This document is not complete. The following are missing:

Part 5 chapter 6A missing Paragraphs 5 to 11 (1 page)

Part 9 Chapter 2 missing paragraphs 39 to end (1 page?)

Part 12, missing most of Chapter 4 to the end of the part.

If you find any of these, please drop me a line.

Many thanks

Colin Hinson.

FLIGHT SIMULATOR MANUAL

General Precision Systems Ltd.,
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JETSTAR FLIGHT SIMULATOR

List of Contents

PART 1

INTRODUCTION

Chapter 1

GENERAL

List of Contents

Introduction

1. The flight simulator comprises a fuselage section mounted on a hydraulically-operated, three-axis motion platform, a radio aids unit with associated chart recorders, and the computing and operating equipment necessary to enable pilots and co-pilots to practise flight operation procedures under instrument flight conditions for the type of aircraft.

Simulator layout

2. The flight-deck and flight instructor's compartment, known as the fuselage section, are mounted on the motion platform. The platform can be moved along its vertical axis, and rotated about its longitudinal and lateral axes, by the extension or retraction of three hydraulic jacks. The floor-mounted computer and radio aids racks are positioned at the rear of the simulator; provision is made for a second instructor's position at the radio aids and charts racks. In addition, the following units form part of the computer installation:

(1) Mains voltage regulator
(2) Input transformer
(3) Motor alternator set
(4) Hydraulic power pack
(5) Air conditioning system connections.

3. The equipment is housed in one room; the computing and radio aids racks are grouped to the rear of the fuselage section, the complete assembly being rectangular in disposition. A minimum headroom of 13 ft 6 in is required for installation of the equipment.

4. The input transformer, voltage regulator, motor alternator and hydraulic unit are floor-mounted. The mains supply contactors to the simulator and the hydraulic unit motion control panel are wall-mounted adjacent to the equipment. The hydraulic unit is enclosed in a sound-proofed structure; the hydraulic system pipes, which feed the motion-platform jacks and control loading units, are installed at floor level, and are bridged and enclosed for protection.

Instructors' controls and equipment

5. The flight instructor supervises crew and cockpit drill and procedures, and controls the simulation of aircraft system faults and emergencies.

6. The radio aids instructor controls the simulated ground radio aids installation which includes large- and small-scale chart recorders; he also controls the wind speed and direction, barometric pressure and airfield altitude.

7. Both instructors are in intercommunication with the pilots and, in addition, can communicate with each other by a private intercom line.

Air conditioning

8. Conditioned air for the fuselage section is taken from the room air-conditioning unit via ducting through the floor of the nose section and into the flight-deck. Air extraction is via separate ducting, at the rear of the flight instructor's compartment, and the air is returned to the air-conditioning unit.

Power requirements

9. The equipment is designed to operate from a 110/120V, 45 to 65c/s, three-phase and neutral supply. The total power consumption is less than 30kVA. The main power supply is routed via three mains isolation switches that respectively control the following inputs:

(1) Input to the simulator via step-up transformer, voltage regulator and motor alternator (SIMULATOR switch)
(2) Input to the hydraulic unit (HYDRAULICS switch)
(3) Input to the simulator services e.g., terminal points for servicing, testing etc. (SERVICE switch).

Chapter 2

FUSELAGE SECTION

List of Contents

Introduction

1. The fuselage section comprises the cockpit and the flight instructor's position and represents stations 144 to 275, inclusive, on the actual aircraft. The fuselage section is mounted on the motion system platform; access to the fuselage is via the permanent steps and the hinged door at the rear. An external platform surrounds the fuselage.

2. Authentic aircraft components are utilized wherever possible; where such utilization is not possible. the external appearance of the simulated equipment is similar to that of the aircraft equipment. Although a full range of equipment is fitted, some items are of dummy form but are retained to conserve an authentic aircraft configuration.

Construction

3. The fuselage is constructed of double-layer wood panels that are secured to a wood framework and also to the motion platform. The flooring consists of metal-backed plywood, faced with vinyl, that is bolted to the motion platform. A servicing panel, secured to the fuselage with Dzus fasteners, is located on the right-hand side of the rear fuselage.

4. The front, side and roof windows are made from translucent acrylic-resin sheet. The two pilots' side windows can be unlatched and slid back to provide additional ventilation as in the aircraft.

Equipment location

5. The simulator caters for either the Sperry or Collins flight system; the respective computers are stowed beneath the rear floor of the motion platform, and selection of either the Sperry or Collins system is made in the cockpit. The system display instruments are located at the pilot's and co-pilot's instrument panels; the alternative instruments are stowed below them on the platform floor. Access to the display instruments in use and equipment at the rear of the instrument panel is via two panels located below the cockpit windows; the panels are retained by spring ball-catches. The nose section is hinged and can be raised clear of the platform to permit the display instruments to be changed and/or other equipment to be serviced.

6. The control columns and rudder bars are connected to artificial-feel units that incorporate signal-generating potentiometers housed within the aft part of the fuselage The artificial-feel units are connected below floor level by transmission bars from each of the controls. Throttle deflection information is provided by lever-operated potentiometers, located in the nose section, that are connected to the throttles by linkages.

Electrical connections

7. Electrical connections to and from the cockpit are taken via cables and multi-pole plugs and sockets to the racks; the cables are secured to support-members within the base.

Air conditioning

8. Cabin pressurization is simulated only to the extent that the instructor can control the readings of the relevant indicators; actual cockpit conditions, however, are controlled by the external air conditioning plant.

Noise effects

9. Noise effects, which vary with changes of airspeed and engine speed, are reproduced in the cockpit by two loudspeakers mounted one within each rear side console.

Flight instructor's compartment

10. The flight instructor's compartment is separated from the cockpit by a doorway and his position is situated on the left-hand side of the compartment. The entrance doorway is situated at the rear of the fuselage and leads directly into the flight instructor's compartment. The entrance door is hinged and can be locked.

Cockpit illumination

11. Instrument panel illumination controls, one for each pilot, are located on the cockpit walls and a further control is located on the cockpit roof; the instructor is provided with an illumination control on his systems panel. The controls enable the intensity of the interior lighting to be varied.

Chapter 3

INSTRUCTORS' STATIONS

List of Contents

Radio aids instructor's station

1. The radio aids instructor's station is situated at the rear of the fuselage section and consists of the following:

(1) The chart console, which forms the upper part of racks 26, 25 and 24
(2) Radio aids racks, numbered 22 and 21, which contain controls and indicators
(3) Interconnection rack 23.

The assembly of the station is L-shaped, rack 23 forming the junction between the two sides.

2. The chart console comprises two 24 x 24 inch chart recorders, each housing a map. The chart recorder on rack 24 houses a map with a 1:250 000 scale, whereas the chart recorder secured to rack 26 houses a map with a $1:10^6$ scale. Chart drive on/off switches are located at the side of each chart.

3. The front panels and units on the racks are identified by the rack number and a two-letter suffix. The first letter (A or B) of the suffix indicates front or rear of the rack; the second letter (A to G) indicates the row in which the unit is located, row A being at the top of the rack. For example:

(1) 21AF indicates rack 21, front and the sixth row from the top.
(2) 22BC indicates rack 22, rear and the third row from the top.

4. The function of each control and indicator on the panel is described in Part 2, Chap.2 (instructors' controls).

5. Each chart recorder comprises a transparent-plastic-covered map above which a movable pen is mounted. The pen is secured to a vertically-mounted bar which can move horizontally across the chart; the pen can also move along the bar and is thus capable of movement in the vertical and horizontal planes. The pen is thus able to move to any part of the map and will record a 'trace' on the transparent chart-cover during such movement. Movement of the pen is achieved by motor-driven chain and cable systems; the drive system is controlled by signals representing the aircraft heading and ground speed. A full description of the chart recorders is given in Part 12, Chap.2.

6. Each rack panel is secured by screws to the welded steel framework of the rack. The functions of the various controls and indicators, together with the name of the panel, are engraved on the front face of the panel or on transparent-plastic labels that are secured by screws. Identification of the panel, and of individual components on that panel, is painted on the rear face of the panel.

7. A shelf is fitted, at convenient working height to the front of the racks; the instructor's intercom socket and press-to-transmit switch are fitted, above shelf level, to the audio panel on rack 21. Test/servicing sockets, one above and one below the shelf, are situated on the narrow vertical panel between the two console charts.

Flight instructor's station

8. The flight instructor's station is situated in the rear of the fuselage section and is separated from the cockpit by a bulkhead; a doorway in the bulkhead provides access to the cockpit. The station contains the instructor's main control panel, which is secured to an angled framework on the port side of the fuselage, a smaller panel (containing the three CLU reset switches) which is secured to the bulkhead, and a seat.

9. The potentiometers and switches on the main control panel enable the instructor to vary flight- and engine-conditions, and to introduce failures and partial-failures of the aircraft systems. Each failure switch is provided with an engraved translucent push-plate, which is illuminated when the switch is operated, to indicate the service or system that has been failed. The lamps adjacent to the partial-failure potentiometers are lit when the potentiometer controls are turned from zero (usually mid-position). In addition to the specified controls, the panels contain flight setting controls, SIMULATOR STOP and HYDRAULICS STOP buttons, "motion on" switch, panel illumination switch and potentiometer, radio and intercom selectors, and aircraft noise switch.

10. The three CLU reset switches on the bulkhead panel enable the instructor to restore operation of the control loading units after the CLU control circuits have been tripped.

Chapter 4

RACK ASSEMBLIES

List of Contents

Introduction

1. The computing and power units of the flight simulator are contained in two double-rack assemblies and in an L-shaped multi-rack assembly. These racks are conveniently positioned near the fuselage and motion structure. The two double-rack assemblies consist of racks 11 and 12 (power supplies), and racks 13 and 14 (flight, engine and system computers). The L-shaped multi-rack assembly comprises the radio aids computer racks (21 and 22), and chart console and power racks 23, 24, 25 and 26.

Unit reference systems

2. The racks house units which are arranged in rows. The position of the individual units in the power racks (11 and 12) and in the radio aids racks (21, 22, 24, 25 and 26) is identified by a two-figure and two-letter reference. The two figures indicate the rack. The first of the two letters is either A (front of the rack) or B (rear of the rack); the second of the two letters identifies the row of units, the top row being A. Thus unit 22AC is the VHF NAV 2 panel in rack 22, front, third row down.

Note...
Exceptions to this rule are the smaller ADF panels (22AD and 22AE) which are mounted in one row.

3. The reference of standard units housed in racks 13 and 14 consists of two figures, indicating the rack number, two capital letters and, in certain instances, an additional letter in lower case. The first of the two capital letters identifies the row of the rack, the second capital letter identifies the position in the row (unit AB being the second unit from the left in first row from the top of the rack), and the lower case letter identifies the section of a unit which contains two or more identical sub-units.

4. The system components, such as relays, feedback- and summing-resistors, etc., on racks 13 and 14, are mounted in relay units or (feedback) trays which are identified by the rack reference (two figures), the row position in the rack (one capital letter) and the tray reference (capital letter T followed by a figure); this figure identifies the position in the row, No. 1 being the first (left-hand) tray in a row. Thus resistor 14C/T5/R8 is mounted in a feedback tray which is positioned in rack 14, third row, fifth tray position in the row (from the left).

5. The reference of servos (rear of racks 13 and 14) includes the rack number (two figures), a capital letter (identifying the row) and a letter S (servo). Thus the reference of No. 4 engine speed servo is 14ES.

6. The reference of servo actuators (rear of racks 13 and 14) consists of the rack reference (two figures), letter A (first row from the top of the rack), letter S (actuator servo) and a lower case letter which identifies the position (from left to right) of the actuator unit in the row. Thus the aileron trim actuator is identified as 14AS/b being in rack 14, first row, and second position from the left.

CONSTRUCTION

Engine and flight computer racks

7. The main framework of racks 13 and 14 is fabricated from mild steel angle sections. Each rack is fitted with rows of standard units contained in crate assemblies which form the rows of the racks. The crates are attached to the racks by screws at the front frame structure of the crate, the rear end of each crate rests on a bracket attached to the rack rear framework. The crates are constructed and electrically wired as individual assemblies.

8. Rack 13 contains seven rows of crates, each row consisting of front and rear assembly. The front assemblies house standard units which are easily removable being plugged in the crate assembly and individually locked, by spring-leaf buttons, in their respective sections of the crate. The rear assemblies contain relay and feedback units which are hinged on a lateral rod to facilitate access. The bottom (seventh) row assembly has hinged feedback units at the front, and hinged relay units at the rear; these units are locked in position by a clip to a centrally disposed bar.

9. The cooling air for the racks is drawn by a fan and via a removable filter unit located underneath the crates; the air is extracted through ports in the roof of the rack by another fan.

10. The racks are enclosed by hinged locking doors at the front, rear and at the sides. The space between racks 13 and 14 is also enclosed with a narrow vertical metal panel which is locked in position with a spring plunger. A servicing power point and a phone jack socket are mounted on the vertical panel.

11. Mounted on the rear door of rack 13 are four actuators, a state panel, three flight computer servos and a power distribution panel. Each actuator is locked in position by a knurled knob which engages a latch in a slot in the door shelf. To unlock the actuator, the knurled knob must be pushed in and turned, thus releasing the latch; the actuator then can be withdrawn for servicing having sufficient length of cable between the unit and the plug mounted on the rack assembly. Each actuator unit contains function potentiometers and a drive motor.

12. The state panel and servos are secured to the door framework. The electrical cables to these units are attached to the terminals on the units and to plugs and sockets within the racks.

13. The side recess of rack 13 is divided into two sections by a vertical panel which carries plugs and sockets for electrical connection to the units in the rack. The front section of the side recess contains the power busbars for the rack. External cables are led out of the rack through an aperture in the rack-roof to a ducting positioned on top of the racks.

14. The cable ducting is made of sheet metal in the form of a box which is supported by box-section pillar through which the cables are routed to the internal wiring of each rack.

15. Rack 14 is similar in layout to rack 13; the state panel position is utilized for an additional engine speed servo.

Power supply racks

16. Racks 11 and 12 are similar in construction to racks 13 and 14. The individual power units in rack 11 rest on channels which are bolted to the vertical rack frames; the front panels in the units are bolted direct to the rack frames, handles being provided to withdraw the units. The rear units rest on channels bolted to the vertical frames.

17. The end of rack 11 contains loomed cabling, some of which terminates in plugs and sockets at a dividing panel. The radio aids fuse panel is located at the bottom front of the rack side recess, and two mains contactors are mounted at the rear.

18. At present, rack 12 is empty and unused.

Radio aids racks

19. The basic construction of the radio aids racks is similar to the computer racks with internal structural variations to allow for the equipment fitted.

20. Racks 21 and 22 contain the units of the radio aids computer; rack 23 houses interconnecting plugs and sockets to the power units and to the charts mounted within and on racks 24, 25 and 26. The racks are enclosed at the rear and side by hinged locking doors. The power units, located at the bottom front of the chart racks are also protected by smaller locking doors.

21. The radio aids instructor's controls and indicators are mounted on the front panels of the individual units which are secured with screws to racks 21, 22 and 24. The chart system controls are placed adjacent to the respective charts. The tape recorder is mounted in the upper part of the audio drawer (on rack 21) which can be withdrawn on runners to gain access to the tape recorder controls.

22. The printed-circuit boards of the station selection digital system are mounted in a crate positioned at the bottom of rack 21. The crate is secured to the vertical rack framework with screws. The rear digital boards slide out on channels, and are locked in position by spring-leaf buttons; the front boards hinge outwards on lateral rods.

23. The bottom units, front and rear, of rack 22, consist of relays on horizontal members which are secured to the vertical framework.

24. At the top or racks 21 and 22 is a double row assembly of units extending across both racks. The assembly, which contains standard plug-in amplifiers, rests on two angled-strip brackets attached to the vertical framework. Components associated with the amplifiers are mounted on hinged tagboards.

25. The rack wiring is carried in a perforated tray in the roof of the racks. An extractor fan is fitted in the roof.

26. Rack 23 forms the angle of the radio aids rack assembly and has two hinged doors at the rear; internally, the rack contains a panel fitted with interconnecting plugs and sockets.

27. The front of racks 24, 25 and 26 contains the two charts; below the charts are two detachable panels, the one at rack 26 is blank, the other contains the frequency repeat panel; below the console shelf are pairs of hinged doors. At the rear, the racks are divided into upper and lower sections, both with pairs of hinged doors. The base of the racks contain power units, the radio aids fuse and switch panel, and the audio filter unit; access to the power units is obtained through either the front or rear lower doors. In the upper section at rack 26 is a suspended tray containing standard a.c. amplifiers for the chart system. At the rear of the tray is a hinged tagboard containing amplifier potentiometers and relays. An extractor fan is situated in the roof of the racks.

PART

OPERATING INSTRUCTIONS

Chapter 1

SWITCHING-ON, DAILY CHECKS AND SWITCHING-OFF

List of Contents

SWITCHING-ON AND DAILY CHECKS

1 The switching-on procedure includes the daily routine switching-on of the simulator power supplies the hydraulic power supply system and starting of all systems. The simulator power distribution system contains safety and tripping devices that are automatically operated in the event of malfunction or mishandling of the equipment.

Procedure

2. Check that the compute/zero switches, on the front panels of all type DE, DEX and DH amplifiers, are set to the compute position, i.e , switch toggles deflected to the left.

3. Ensure that all LT and HT switches on the rack distribution panels (racks 13 and 14) are set to ON

4. Ensure that the LT and HT switches on the radio aids fuse and switch panel (rack 24) are set to ON.

5. Check that the simulator hydraulics mains isolation switch is set to OFF.

6. Check that the Mackie motor alternator mains-isolation switch on the alternator fuse and isolation box is set to ON

7. Set the simulator mains isolation switch to ON. This action connects the mains three-phase supply to the step-up transformer and to the mains regulator which feeds the mains supply to the mains control panel on rack 11. Check that the three MAINS ON lamps on the fuse and indicator panel (11A) are lit.

8. Press the simulator LT START push-button switch on the mains control panel (11C).

9. Ensure that all rack fans are operating.

10. Press the simulator HT START push-button switch on the mains control panel (11C).

11. When all power supplies are switched on, as confirmed by the lit MAINS ON lamps on the fuse and indicator panel, HT ON lamp on the mains control panel, and LT ON and HT ON lamps on the rack distribution panels, and after a nominal power-stabilization period of 15 minutes, check the accuracy of all power supply lines above ±50V by means of the voltage calibrator, type 6A, on rack 11. Select the individual supplies by the selector switch and check on the adjacent galvanometer that the supplies are within the following limits:

(1)	-50V	-	±0·1 per cent
(2)	+50V	-	±0·1 per cent
(3)	-300V	-	±0·2 per cent
(4)	+300V	-	±0·2 per cent
(5)	-500V	-	±0·4 per cent.

Note...

Preliminary readings should be made with the HIGH SENS/OFF/LOW SENS switch in the LOW SENS position. Adjust the outputs of the appropriate power units, as required; the final readings and adjustments of the output voltage must be made with the sensitivity switch in the HIGH SENS position.

12. Set the MANUAL/FLIGHT motion control switch on the motion control panel (MCB), to MANUAL.

13. Check that the hydraulic pressure gauge (on the hydraulic power unit) indicates an accumulator pressure of 750 lb/in^2 and check that the accumulator hydraulic fluid contents are adequate (approximately half-scale reading on the hydraulic contents sight gauge).

WARNING...

ENSURE THAT ALL PERSONNEL ARE WELL CLEAR OF THE MOTION PLATFORM BEFORE SWITCHING ON THE HYDRAULIC POWER TO THE MOTION SYSTEM AND ENSURE THAT NO UNSECURED EQUIPMENT IS IN/ON THE FUSELAGE OR ON THE MOTION PLATFORM.

14. Set the three manual control potentiometers (on MCB) fully counter-clockwise.

15. Set the hydraulics main isolation switch to ON.

16. Press the green START push-button (on MCB).

17. Check that the hydraulic pressure increases to 1500 lb/in^2.

18. Operate the MOTION switch (on MCB); the lamps in this switch and in the RESTRICTED FLOW switch (on MCB) light, and the motion platform will rise, under restricted flow, to the operational position.

19. Check that the motion platform responds to the three manual controls (on MCB).

20. Within 45 seconds the full flow of hydraulic fluid should be obtained, whereupon the lamp in the RESTRICTED FLOW switch (on MCB) extinguishes.

21. Check again the operation of the motion platform by means of the three manual control potentiometers (on MCB). On completion of the tests reset the three potentiometers to the fully counter-clockwise positions.

Note...

Before placing the motion system under flight computer control, ensure that the flight computer is in a steady state and the simulator is "groundborne", i.e., the MAIN-WHEELS TOUCHDOWN and NOSEWHEEL TOUCHDOWN lamps, on state panel 13BS, are lit.

WARNING...

ENSURE THAT NO PERSONNEL ARE IN THE VICINITY OF THE FLYING CONTROLS WHEN THE MANUAL/FLIGHT SWITCH IS SET TO FLIGHT, AND WHEN THE CONTROL LOADING UNITS (CLU) RESET SWITCHES ARE OPERATED.

22. Set the MANUAL/FLIGHT switch (on MCB) to the FLIGHT position. Check that the hydraulic fluid flow is again restricted and that the lamp of the RESTRICTED FLOW switch (on MCB) lights.

23. Operate the RUDDER, ELEVATOR and AILERON switches on the flight instructor's panel XH/AB; ensure that the CLU systems are reset (switch lamps extinguished) and the respective flying controls move freely throughout their operating ranges.

24. Operate the master MOTION switch XF/AH/51 on the flight instructor's main panel. The switch lamp should light and full hydraulic fluid flow should be obtained within 45 seconds.

25. Check that the motion platform settles in the "groundborne" position, i.e., the three jacks are extended approximately one fifth of their full travel.

26. The simulator is now in a state of readiness for the daily functional checks, pre-flight checks, etc.

SWITCHING-OFF

27. Set the MANUAL/FLIGHT switch (on MCB) to MANUAL, and set the MOTION switch (on MCB) to the off position, i.e., switch lamp extinguished.

28. Set the hydraulics mains isolation switch to OFF.

29. Set the simulator mains isolation switch to OFF.

Chapter 2

INSTRUCTORS' CONTROLS

List of Contents

Introduction

1. The flight instructor's controls, switches and indicators are contained on two panel assemblies in the fuselage section of the flight simulator; the controls, switches and indicators used by the radio aids instructor are mounted on panels on the radio aids racks 21, 22, 23, 24, 25 and 26.

2. By operation of the controls and switches, the instructors can preset a variety of conditions to simulate those experienced by the pilots during an actual flight. Functionally, the controls are of two types:

(1) Controls which provide adjustment of the basic atmospheric and flight conditions.
(2) Fault switches and controls by means of which faults can be introduced into the simulated aircraft systems.

3. A description of the function and operation of each control is included in the relevant chapters of this manual; this chapter describes the immediate effects or indications that occur when the controls are operated. The order in which the controls and switches are described follows their order of location starting at the top left-hand corner of each panel.

FLIGHT INSTRUCTOR'S STATION

4. The flight instructor's station, in the rear section of the fuselage, is fitted with two panels: the control loading units (CLU) reset panel XH/AB on the right-hand side of the bulkhead separating the cockpit and fuselage-sections of the simulator, and the main flight control panel assembly XF on the left-hand side.

5. The fail switches mounted on panel XF are fitted with translucent push-plates which are illuminated when the switches are operated. The setting of partial-failure potentiometers is indicated by adjacent lamps that light when the potentiometer controls are rotated from their normal positions (usually mid-position).

PANEL XH/AB

Rudder, elevator and aileron reset switches

6. The RUDDER, ELEVATOR and AILERON reset switches, /S1, /S2 and /S3, are provided for resetting the respective control loading systems. The three switches must be operated, after switching on the simulator power supplies, to render the control loading systems operational.

7. When a system is tripped, a lamp in the push-plate of the corresponding switch lights. If any one of the three control loading systems should trip, due to malfunction, the remaining two systems then operate on reduced hydraulic power. Full hydraulic power for the two serviceable systems can be obtained by pressing either one or both of the two unlit switches.

PANEL XF/AJ

Flight altitude potentiometer

8. The FLIGHT ALTITUDE potentiometer /RV4 enables the instructor to vary the indicated flight altitude (between 0 and 60 000 ft) on the dual altimeter and differential pressure indicator RJ/AC (of the cabin air conditioning system) to obtain readings corresponding to the actual flight altitude.

Cabin altitude potentiometer

9. The CABIN ALTITUDE potentiometer /RV3 enables the instructor to vary the indicated cabin altitude (between 0 and 60 000 ft) on the dual altimeter and differential pressure indicator RJ/AC.

Cabin rate of climb potentiometer

10. The CABIN R O C potentiometer /RV2 is provided for manual adjustment of the indicated cabin rate of climb which is displayed on the CABIN RATE OF CLIMB indicator RJ/AH.

Cabin temperature potentiometer

11. The CABIN TEMP potentiometer /RV1 enables the instructor to vary the indicated cabin temperature, displayed on the CABIN TEMP. indicator RF/AC, between the limits 0° and 120°F.

PANEL XF/AK

12. The majority of controls and switches on panel XF/AK affect the aircraft electrical system. Twelve of these switches (/S13 to 20 and /S22 to 25 inclusive) trip, when operated, selected circuit breakers that supply certain aircraft systems; these circuit breakers are referred to as "faultable" circuit breakers. A description of the operation of the faultable circuit breakers is included in the electrical system (Part 10, Chap. 1).

Generator 1 and 2 switches

13. The GEN 1 and GEN 2 switches /S29 and /S30 enable the instructor to simulate, individually, failure of the No.1 and 2 engine-driven generators. When the switches are operated, the respective GEN OUT lamp, on panel RC, lights, indicating generator failure. The readings of the associated LOAD meters, on panel RC, then decrease to zero.

Generator 1 and 2 voltmeter potentiometers

14. The generator 1 and generator 2 VOLTS potentiometers, /RV4 and /RV2 respectively, enable the instructor to simulate generator output variations from 0V to 32V; the output voltage is indicated on the D C VOLTMETER RC/AC provided that the adjacent VOLTMETER SELECTOR RC/AD is set to the GEN 1 or GEN 2 position as required.

Generator 1 and 2 ammeter potentiometers

15. The generator 1 and generator 2 AMPS potentiometers, /RV5 and /RV3 respectively, provide simulation of output load fluctuations of the No.1 and/or No.2 generators. The loadings are indicated by the No.1 and No.2 LOAD meters RC/AE and RC/AF, respectively.

Battery potentiometer

16. The BATTERY potentiometer /RV1 enables the instructor to vary the simulated battery output voltages between the limits of 0V to 24V when the batteries are not being charged from the generators. The battery output is indicated on the D C VOLTMETER RC/AC provided that the adjacent VOLTMETER SELECTOR RC/AD is set to the BAT position.

Inverter switches

17. The MAIN and STANDBY INVERTER switches, /S26 and /S27 respectively, provide simulation of individual failure of the No.1 and No.2 inverters. When the inverters are failed, the corresponding NO.1 and/or NO.2 MAIN BUS OUT lamps, on panel RE, light. The warning indication is repeated by the INVERTER OUT lamp on the annunciator warning panel.

Ignitor 2 circuit breaker switch

18. The IGNITOR 2 switch /S22, when operated, simulates an electrical fault of the No.2 engine ignitor; the No.2 engine cannot then be started. Failure of the No.1, 3 and 4 engine ignitors is not simulated.

Oil pressure 1 circuit breaker switch

19. The OIL PRESS 1 switch /S23 enables the instructor to simulate electrical failure of the No.1 engine pointer of the dual OIL PRESS indicator AC/CC. When /S23 is operated, the engine No.1 pointer stops, and does not follow oil-pressure variations due to varying engine speed; the OIL PRESS LOW warning lamp on the annunciator warning panel remains extinguished, even if the engine speed is reduced below 37·6%, at which speed the OIL PRESS LOW warning should occur.

EPR4 circuit breaker switch

20. The EPR4 switch /S24 enables the instructor to simulate electrical failure of the No.4 engine P.R. gauge AC/AU. When switch /S24 is operated, the pointer of No.4 P.R. gauge returns to the minimum indicated engine pressure ratio, i.e., 1·2.

Hydraulic pressure system 1 circuit breaker switch

21. The HYD-PRESS SYSTEM 1 switch /S25, when operated, prevents the No.1 hydraulic system from being automatically shut off when the FIRE 2 PULL handle is pulled.

Landing gear circuit breaker switch

22. The LANDING GEAR switch /S17, when operated, simulates failure of the nosewheel steering mechanism; the steering system becomes inoperative and the nosewheel will castor.

Flaps circuit breaker switch

23. The FLAPS switch /S18 enables the instructor to simulate electrical failure of the leading-edge and trailing-edge wing flaps. When switch /S18 is operated, the pointers of the LEADING EDGE and TRAILING EDGE indicators, AC/BL and AC/BM, respectively, turn to the maximum clockwise position corresponding approximately to the LE and TE FLAPS inscription, thus indicating flap system failure. The flaps will then remain at, or continue to, the position selected prior to failure.

Mach trim circuit breaker switch

24. The MACH TRIM switch /S19 enables the instructor to simulate electrical failure of the Mach trim compensator. The MACH TRIM COMP OUT warning lamps SA/AM and CF/AG light if the Mach trim compensator is "on" when the failure is introduced.

De-ice circuit breaker switch

25. The DE-ICE switch /S20 enables the instructor to simulate electrical failure of the wing and tailplane de-icing system.

Normal bus tie circuit breaker switch

26. The NORMAL BUS TIE switch /S13, when operated, disconnects the normally-made connection between the main and essential d.c. busbars. The essential busbar can be then energized from the aircraft battery or from the ignition and start busbar.

Flight direction 1 heading circuit breaker switch

27. The FLT DIR 1 HEADING switch /S14 enables the instructor to fail the compass cards contained in the indicators of the Collins and Sperry flight systems and in the C6F compasses. The compass cards then remain in the position reached at the time of failure.

ADF 1 circuit breaker switch

28. The ADF 1 switch /S15, when operated, causes complete electrical failure of the simulated ADF 1 receiver.

Compass 2 circuit breaker switch

29. The COMP 2 switch /S16, when operated, fails the starboard C6F compass display instrument AC/BV.

Ground supply switch

30. The GROUND SUPPLY switch /S21, when operated, simulates the connection of ground battery supplies to the aircraft.

Vertical gyro 1 switch

31. The VERT GYRO 1 switch /S6, when operated, causes failure of the pitch and roll bars in the pilot's Collins and Sperry flight director indicators; in addition, the gyro warning flags in these instruments are displayed (GYRO flag in the Collins approach horizon, and G marker in the Sperry flight director).

Vertical gyro 2 switch

32. The VERT GYRO 2 switch /S7 operates in a similar manner to the VERT GYRO 1 switch /S6, causing failure of pitch and roll bars in the co-pilot's Collins approach horizon and Sperry flight director indicators.

IFS attitude switch

33. The IFS ATT 1 switch /S8, when operated, causes failure of the Collins and Sperry integrated flight systems computers with consequent failure of the flight systems indicators.

Compass 1 switch

34. The COMP 1 switch /S9, when operated, fails the heading indicator card contained in the port C6F compass, AC/BV. The indicator card then remains in the position attained at the time of failure.

Airspeed indicator switch

35. The ASI 1 switch /S10 enables the instructor to fail the pointer of the pilot's airspeed indicator AA/AD. The indicator pointer then remains in the position reached at the time of failure.

Sperry switch

36. The SPERRY switch /S11 forms part of the Sperry/Collins selection system. The switch is spring-biased to the "off" position and, when operated, releases a set of relays the contact sets of which then connect the energizing supplies to the Sperry flight system. When the Sperry system is required, the Sperry display instruments are placed in position and switch /S11 is depressed. After switching on the simulator, the Sperry system is automatically selected.

Collins switch

37. The COLLINS switch /S12 forms part of the Sperry/Collins selection system. The switch is spring-biased to the "off" position and, when operated, the contact sets (para.36) then connect the energizing supplies to the Collins flight system instruments When the Collins system is required, the Sperry instruments are removed and the Collins instruments are placed in position; switch /S12 is then depressed. After switching on the simulator, the Sperry system is automatically selected, and if the Collins system is required, switch /S12 must be operated.

PANEL XF/AL

Generator 3 and 4 switches

38. Operation of the GEN 3 and GEN 4 switches, /S11 and /S10 respectively, is similar to that described for the GEN 1 and GEN 2 switches (para.13); the corresponding No.3 and No.4 GEN OUT lamps and LOAD meters will be affected.

Windscreen inverter switch

39. Operation of the W'SCREEN INVERTOR switch /S9 is similar to that relevant to the MAIN and STANDBY inverter switches described in para.17. Warning of failure is given by the WINDSHIELD BUS OUT lamp RE/AE.

Supply doors switch

40. The SUPPLY DOORS switch /S8 operates a relay that simulates disconnection of the ground supplies and closing of the ground battery supply doors.

Stall vanes switch

41. The STALL VANES switch /S12 must be operated by the instructor when ground tests of the pre-stall warning system are performed. Operation of /S12 simulates deflection of the stall sensor vanes.

Generator 3 and 4 voltmeter potentiometers

42. The operation of the generator 3 and 4 VOLTS potentiometers, /RV6 and /RV4 respectively, is similar to that of the generator 1 and 2 VOLTS potentiometers,

described in para. 14. The VOLTMETER SELECTOR RC/AD must be set to the GEN 3 or GEN 4 position, as required.

Frequency potentiometers

43. The FREQUENCY potentiometers /RV1, /RV2 and /RV3 enable the instructor to vary the frequency of three simulated 400c/s inverters from 350c/s to 450c/s, as indicated on the FREQ METER RE/AD.

Generator 3 and 4 ammeters potentiometers

44. The operation of the generator 3 and 4 AMPS potentiometers, /RV7 and /RV5 respectively, is similar to that of the generator 1 and 2 AMPS potentiometers described in para. 15; the indication of the corresponding No. 3 and No. 4 LOAD meters will be affected.

De-ice pressure switch

45. The DE-ICE PRESS switch /S13 enables the instructor to vary the reading, between 0 and 35 PSI, on the DE-ICER PRESS indicator mounted on the de-ice timer panel SF/AA.

PANEL XF/AM

Outside air temperature potentiometer

46. The O A T potentiometer /RV4 enables the instructor to vary the apparent outside air temperature by $\pm 35^{\circ}C$, with consequent changes in the indication of the FREE AIR TEMP. gauge AC/BU and of other flight instruments affected by atmospheric temperature changes.

Turbulence potentiometer

47. The TURBULENCE potentiometer /RV3 enables the instructor to vary the intensity of artificially-generated atmospheric turbulence and gust effects.

Ice switch

48. The ICE switch /S8 enables the instructor to introduce airframe and pitot head icing effects that increase over a period of approximately one minute.

Crash switch

49. The CRASH switch /S6 enables the instructor to simulate the conditions of a crash-landing. The "crash" effects are initiated on touchdown and include rapid reduction to zero of the airspeed, and failure of the simulated aircraft electrical supplies.

Reset systems switch

50. The RESET SYSTEMS switch /S7 must be operated to reset all "one shot" systems, e.g., dragchute and/or the landing gear emergency release system.

Note...
The emergency landing gear system must be first reset mechanically by the operation of a reset lever located below panel XF/AH.

Freeze switch

51. The FREEZE switch /S5 enables the instructor to immobilize the flight simulator and the flight instruments during a flight training exercise. The exercise may, subsequently, be continued from the point at which it was interrupted, by releasing /S5.

Weight potentiometer

52. The WEIGHT potentiometer /RV2 enables the instructor to vary the aircraft weight between 20 000 and 50 000 lb.

Centre of gravity potentiometer

53. The C G potentiometer /RV1 enables the instructor to vary the position of the centre of gravity, (normally set at $0{\cdot}33\bar{c}$, where $\bar{c}$ = wing mean chord), to correct for changes in load distribution.

PANEL XF/AB

Fuel tank run switches

54. Six TANK RUN switches /S25, /S20, /S15, /S9, /S4 and /S1 enable the instructor to simulate depletion of the six fuel tanks, indicated on the respective FUEL QUANTITY gauges at a fixed rate of 850lb/hr. These switches are also used for fuel jettisoning, in which instance the respective TANK RUN switch and the REFUEL switch (para.55) must be operated at the same time.

Tank refuel switches

55. Six REFUEL switches /S26, /S21, /S16, /S10, /S5 and /S2 enable the instructor to simulate individual refuelling of the six fuel tanks. The REFUEL switches should be set to off when the required quantity of fuel is indicated on the respective FUEL QUANTITY gauge. Fuel jettison of each tank is achieved by operation of the respective TANK RUN and REFUEL switches at the same time.

Low pressure switches

56 Six LOW PRESSURE switches /S27, /S22, /S17, /S11, /S6 and /S3 simulate, when operated, insufficient pressure of fuel from any of the six fuel tanks. When a LOW PRESSURE switch is operated, the corresponding LOW FUEL PRESS lamp on panel CA, and the FUEL PRESS LOW lamp on the annunciator warning panel, light.

Fuel filter switches

57. The four FUEL FILTER switches /S23, /S18, /S12 and /S7 simulate, when operated, individual clogging of the four engine fuel filters. When a filter is clogged, the corresponding FUEL FILTER CLOGGING lamp on panel SA lights.

Fuel temperature switches

58. The four FUEL TEMP. switches /S24, /S19, /S13 and /S8 enable the instructor to simulate, individually, failure of the four fuel-heaters. Operation of the FUEL TEMP. switches by the instructor results in the FUEL FILTER CLOGGING lamps on panel SA remaining lit even after the correct de-icing procedure has been performed.

Interconnect valve lamp

59. The INTERCONNECT VALVE lamp /LP14 lights when the crossfeed switch CA/AZ, on the fuel control panel, is set to the crossfeed position.

PANEL XF/AC

60. The switches contained on this panel are all fail switches which, when operated, cause a failure to occur in the relevant aircraft system.

Speedbrake switch

61. The SPEEDBRAKE switch /S9 enables the instructor to fail the operation of the speedbrake; when failed, the speedbrake will remain in the position last selected.

Flaps switch

62. The FLAPS switch /S8 enables the instructor to fail the operation of the leading-edge and trailing-edge wing flaps, and the flaps remain in the position last selected.

Brakes switch

63. Failure of the hydraulic supply to the wheelbrakes can be simulated by the operation of the BRAKES switch /S7. No warning of this failure is given to the pilot until the simulated hydraulic accumulator has been discharged by four brake-pedal applications. The brakes then become inoperative unless the stand-by hydraulic system is selected.

Mainwheels door unlock switch

64. The MAIN WHEELS DOOR UNLOCK switch /S6 enables the instructor to simulate failure of the mainwheel doors to unlock when landing gear DOWN is selected. In this instance, the nosewheel proceeds to extend and lock down, and the nosewheel green-coloured lamp on panel AC/BQ lights. Indication of failure of the mainwheels to lock down is given by the red-coloured lamp, which remains lit, in the handle of the landing gear selector lever.

Mainwheels switch

65. The MAIN WHEELS switch /S5, when operated, causes the mainwheels section of the landing gear to fail to lock up or down when a landing gear UP or DOWN function is selected.

Nosewheel switch

66. The NOSE WHEEL switch /S4, when operated, causes the nosewheel section of the landing gear to fail to lock up or down when a landing gear UP or DOWN function is selected.

Stabilizer switch

67. A stabilizer runaway condition is simulated by operation of the STABILISER switch /S3. When this switch is operated, the pitch trim actuator drives to the maximum NOSE UP position, i.e., 10^{o} indicated on the HORIZ STAB indicator on panel CB.

Hydraulics 1 switch

68. The HYD 1 switch /S2 enables the instructor to fail the simulated No.1 hydraulic system. The auxiliary hydraulic system pump is also failed. When switch /S2 is operated, the No.1 system accumulator normally discharges in approximately 100 seconds, but the time factor is reduced almost to zero if the pilot operates any of the services powered by the No.1 system.

Hydraulics 2 switch

69. The HYD 2 switch /S1 enables the instructor to fail the simulated No.2 hydraulic system in a similar manner to that effected by the HYD 1 switch (para.68).

PANELS XF/AD, /AE, /AF and /AG

70. Panels XF/AD, /AE, /AF and /AG are identical and each contains instructor's fail switches and controls for one of the four simulated engines. Each switch and control affects one engine and its associated indicators individually; only the switches and controls on panel XF/AD, pertaining to engine No.1, are described.

RPM potentiometer

71. The RPM potentiometer /RV6 enables the instructor to vary the speed of the simulated No.1 engine by ±20 per cent, as indicated on the respective PERCENT RPM gauge.

Engine temperature potentiometer

72. The ENG TEMP potentiometer /RV5 enables the instructor to vary the exhaust gas temperature of the simulated No.1 engine by ±300°C, as indicated on the respective EXH.TEMP. gauge.

Fail switch

73. The FAIL switch /S10 enables the instructor to extinguish the simulated No.1 engine, when "lit", or to prevent the engine from "lighting" during start up.

Hot start switch

74. Operation of the HOT START switch /S11, prior to starting the simulated No.1 engine, enables the instructor to introduce a "hot start" condition. Starting the No.1 engine, with switch /S11 operated, causes the indicated engine temperature, on the EXH.TEMP. gauge, to rise above the normal 750°C to 1000°C.

Reverse switch

75. The REVERSE switch /S12 enables the instructor to fail the operation of the simulated reverse thrust mechanism of the No.1 engine. If switch /S12 is operated before the pilot selects reverse thrust, the reverse thrust mechanism will fail to operate; if /S12 is operated while reverse thrust is in use, the reverse thrust mechanism will fail to revert to forward thrust when this latter facility is selected.

Engine pressure potentiometer

76. The ENG PRESS potentiometer /RV4 enables the instructor to vary, by ±1, the reading of the No.1 engine P.R. gauge, thus simulating pressure variations of No.1 engine.

Fuel flow potentiometer

77. The FUEL FLOW potentiometer /RV3 enables the instructor to vary, by ±3000 lb/h, the reading indicated on the No.1 engine fuel flow gauge.

Fire zone 1 switch

78. The FIRE ZONE 1 switch /S7 enables the instructor to simulate a fire in, or overheating of, the aft zone of the No.1 engine, indicated to the pilot by intermittent "flashing" of the lamps contained in the FIRE 1 PULL handle.

Fire zone 2 switch

79. The FIRE ZONE 2 switch /S8 enables the instructor to simulate a fire in, or overheating of, the forward zone of the No.1 engine, indicated to the pilot by a steady lit condition of the lamps contained in the FIRE 1 PULL handle.

Fail fire warning switch

80. The FAIL FIRE WARNING switch /S9 enables the instructor to simulate failure of the warning lamps contained in the FIRE 1 PULL handle.

Oil temperature potentiometer

81. The OIL TEMP potentiometer /RV2 enables the instructor to vary, by $\pm 100^{o}C$, the reading of the No.1 OIL TEMP. gauge AC/BW.

Oil pressure potentiometer

82. The OIL PRESS potentiometer /RV1 enables the instructor to vary, by $\pm 50\ lb/in^2$ the reading of the No.1 pointer of the OIL PRESS gauge AC/CC.

PANEL XF/AH

Panel lights switch

83. The PANEL LIGHTS switch /S8, when operated, connect the supply to the two tubular lamps mounted above the instructor's panels. These lamps provide illumination of the instructor's station.

Motion switch

84. Operation of the MOTION switch /S7 effects full operating condition of the motion system, provided that the MANUAL/FLIGHT switch MCB/S1 (motion control box) is set to FLIGHT and the hydraulic pump is operating.

Panel lights control

85. The PANEL LIGHTS control /T1 enables the instructor to vary the brightness of the tubular lights (para.83).

Simulator stop switch

86. The SIMULATOR STOP switch /S6 is primarily intended for emergency use. It enables the flight instructor to disconnect the electrical power supplies to the simulator. When switch /S6 is operated, the two main contactors (11X/CR1 and /CR2) are released and the a.c. supplies to the power racks and to the radio aids console are disconnected.

Hydraulics stop switch

87. The HYDRAULICS STOP switch /S5 is primarily intended for emergency use. It enables the flight instructor to stop the hydraulic power supply to the motion and to the control loading systems. When switch /S5 is operated, the electric power supply to the motor-driven pump in the main hydraulic power supply unit is disconnected; the simulator motion platform then "settles" and the control loading system becomes inoperative.

Private lamp

88. The PRIVATE lamp, /S3LP, housed in the translucent plate of switch /S3 (not used), when lit, indicates that the radio aids instructor wishes to communicate via the instructors' private line.

Noise switch

89. The NOISE switch /S4 enables the instructor to switch on or off the simulated aircraft and engine noise fed to the cockpit loudspeaker units.

PTT/LTT switch

90. The PTT/LTT, (press-to-talk/lock-to-talk) switch /S2, is part of the flight instructor's audio system, and it enables him to communicate with the console instructor and with the crew.

Microphone selector switch

91. The five positions of the microphone selector switch /S1, which are: HF, VHF 1 VHF 2, I/C and PVT, enable the instructor to participate in these audio systems, (except HF, which is not used), and to communicate with the radio aids instructor via the private line (PVT position).

RADIO AIDS CONSOLE

LARGE-AREA CHART (RACKS 26 AND 25)

Manual positioning controls

92. The manual positioning controls 25AA consist of two large knobs located at the top right-hand edge of the large-area chart assembly 26AA; the knob-shafts are coupled to a pen-drive mechanism which provides direct manual control of the pen position.

On/off switch

93. The ON/OFF switch 25AA/S1 controls the supply to the large chart recorder pen motors which are normally switched-off during manual positioning.

SMALL-AREA CHART (RACKS 24 AND 23)

94. The small-area chart controls include manual positioning controls 24AA, and the motor ON/OFF switch 23AA/S1 that function identically to those of the large-area chart (para. 92 and 93).

FREQUENCY REPEAT PANEL 24AB

OM lamp

95. The OM (outer marker) lamp /LP6 flashes in synchronism with the marker ident code in the following two instances:

(1) The aircraft is in the reception area of the ILS outer marker beacon, and AUTO operation of the marker system is selected by the ILS MARKERS switch 21AG/S3 (para.164).
(2) The MANUAL operation of the marker system is selected by the ILS MARKER switch 21AG/S3, and the FANS switch 21AG/S2 (para.162) is set to the OM position.

MM lamp

96. The MM (middle marker) lamp /LP7 indicates, when lit, reception of the ILS middle marker signal, and operates in a similar manner to the OM lamp (para.95).

Airways lamp

97. The AIRWAYS lamp /LP8, which is not controlled automatically, operates similarly to the OM and MM lamps (para.95 and 96 respectively), but flashes in synchronism with one of the following marker idents selected by the marker selector (FANS) switch 21AG/S2 (para.162):

(1) ILS inner marker (marker selector switch is set to IM)
(2) Fan markers 1 to 5 inclusive (marker selector switch set to the respective position)
(3) Z marker (marker selector switch set to Z).

HI lamp

98. The HI lamp /LP4, when lit, indicates that high marker-receiver sensitivity has been selected, by means of the pilots' MKR selector switch CF/AK.

LO lamp

99. The LO lamp /LP5, when lit, indicates that low marker-receiver sensitivity has been selected by the pilots' MKR selector switch CF/AK.

Digital indicators, VHF COMM 1, HF and VHF COMM 2

100. The two digital indicators for the VHF COMM 1 and VHF COMM 2 systems provide an illuminated digital read-out of the frequency selected by the pilot or co-pilot A digital indicator for the HF system is also fitted but is not functional.

VHF COMM 1, HF and VHF COMM 2 lamps

101. The VHF COMM 1 and VHF COMM 2 lamps, /LP1 and /LP3 respectively, light when the appropriate VHF COMM system is in use and the pilot or co-pilot has pressed his PTT switch. HF lamp /LP2 is fitted but is not functional.

VHF COMM 1, HF and VHF COMM 2 fail switches

102. The VHF COMM 1 and VHF COMM 2 FAIL switches, /S1 and /S3 respectively, enable the instructor to fail, individually, each of the simulated VHF COMM receivers. The HF fail switch /S2 is fitted but is not operational.

FUSE AND SWITCH PANEL 24 BE (REAR)

LT switch

103. The LT switch /S1 controls the a.c. supply to the l.t. heater transformers of the radio aids power units.

HT switch

104. The HT switch /S2 controls the a.c. supply to the h.t. circuits of the radio aids power units. A contact of a thermal delay relay (energized by /S1) is wired in series with /S2 to provide automatic delay for the h.t. supplies if both the HT and LT (para.103) switches are operated at the same time.

VHF NAV 1 and VHF NAV 2 PANELS 22AB AND 22AC

105. The VHF NAV 1 and 2 panels are identical except for positional references; only the controls, lamps, and instruments on the VHF NAV 1 panel 22AB are described.

GP switch

106. The GP angle selector switch /S1 enables the instructor to set the glidepath angle between 2^{o} and 6^{o} in increments of $0 \cdot 25^{o}$.

Localizer course line control

107. The LOCALISER COURSE LINE control /RS1 enables the instructor to set the bearing of a simulated ILS localizer transmitter (corresponding to the "runway in use" course line) to any angle through 360^{o}.

MM potentiometer

108. The MM potentiometer /RV2 enables the instructor to set the position of the ILS middle marker to any distance along the localizer course line between 0·25 nautical miles and 5 nautical miles from the runway threshold.

GP fail switch

109. The GP FAIL switch /S2, when operated, disconnects the glidepath deviation signals from pilots' course indicators and causes, on the Sperry PDI, the glide slope scale to retract and reveal the GS warning marker, and, on the Collins course indicator and approach horizon, the GS flags to appear.

Receiver fail switch

110. The RECEIVER FAIL switch /S4, when operated, fails the VHF NAV 1 receiver. If /S4 is operated when the VHF NAV 1 receiver is in tune with one of the eight stations, the respective "in tune" indicator lamp (para.117) on this panel will extinguish, and the relevant receiver information will not be fed to the crew instruments.

Localizer fail switch

111. The LOC FAIL switch /S3, when operated, disables the course deviation bars on the Sperry and Collins course indicators fitted to the pilot's instrument panels AA/AW and AA/AH. The NAV warning flags appear in these instruments and the LOC flag appears in the Collins flight approach horizon AA/AB on pilot's instrument panel.

OM potentiometer

112. The OM potentiometer /RV1 enables the instructor to set the position of the ILS outer marker to any distance along the localizer course line between 2 nautical miles and 10 nautical miles from the runway threshold.

Aircraft to station bearing indicator

113. When the VHF NAV channel is correctly tuned, the AIRCRAFT TO STATION bearing indicator /X1 displays the aircraft-to-VHF NAV 1 station bearing.

DME on/off switch

114. The DME ON/OFF switch /S5 enables the instructor to fail the VHF NAV 1 DME system. When the system is failed, the OFF flag appears in the pilot's DME indicator.

DME override lamp

115 The DME O'RIDE lamp /LP9 lights when the SEARCH O'RIDE/NORM switch CF/AA, on the pilot's VHF NAV 1 frequency controller, is set to O'RIDE.

Aircraft to station distance indicator

116 The AIRCRAFT TO STATION distance indicator /M1 displays the aircraft-to-VHF NAV 1 station distance between 0 and 200 nautical miles, repeating the reading displayed on the pilot's DME distance indicator.

Station selected lamps

117. The eight (1 to 8) STATION SELECTED lamps /LP1 to /LP8, inclusive, provide indication of the VHF station to which the VHF NAV 1 receiver (receiver 3) is tuned.

ADF PANELS 22AD AND 22AE

118. The ADF 1 and 2 panels are identical and only the indicators and switches on the ADF 1 panel 22AD are described.

Fail switch

119. The FAIL switch /S1 enables the instructor to fail the ADF 1 receiver. If switch /S1 is operated when the ADF 1 receiver is "in tune" with one of the eight stations, the respective "in tune" lamps (para. 121) on this panel will extinguish.

ADF bearing indicator

120. The ADF bearing indicator /X1 displays the aircraft true bearing from an ADF "in tune" ground station.

Tuning indicator lamps

121. The eight (1 to 8) tuning indicator lamps /LP1 to /LP8, inclusive, provide indication of the MF station to which the ADF 1 receiver ("receiver 1") is tuned.

GCA PANEL 22AF

Heading indicator

122. The heading indicator displays the aircraft true heading.

ATC lamp

123. The ATC lamp /LP1 lights when the ATC TRANSP (transponder) switch CF/AK (on the centre stand) is switched on.

Magnetic variation control

124. The MAG VAR control /RS1 enables the instructor to introduce magnetic variation into the aircraft heading supplied to the chart recorder system.

Glide slope indicator

125. The glide slope indicator, /M4, is a centre-zero instrument that displays the deviation of the aircraft from the glidepath up to a maximum of ±250 ft.

GCA localizer deviation indicator

126. The localizer deviation meter, /M5, is a centre-zero instrument, calibrated $\pm$1200 ft, that displays the aircraft deviation from the GCA localizer course line.

GCA course line control

127. The GCA COURSE LINE control /RS1 enables the instructor to set a GCA runway course line between 0° and 360°

GCA distance indicator

128. The GCA distance meter, /M3, displays the aircraft-to-runway threshold distance. The meter is calibrated from 0 to 15 nautical miles.

FT x 10 switch

129. The FT X 10 scale-change switch /S2 sets the range of the GCA localizer deviation meter /M5 (para. 126). When /S2 is set to the normal position the calibration of /M5 is 0 to $\pm$1200 ft; setting /S2 to FT X 10 changes the scale to 0 to $\pm$12 000 ft.

Clock

130. The 8-day clock /M6 is provided with an independent time-of-flight scale, a time-of-flight start/stop knob, a time-of-flight facility selection knob and a winder.

GCA station selector switch

131. The GCA STATION selector switch /S1 enables the instructor to allocate any one of the eight available stations to the GCA channels.

Altimeter

132. Altimeter /M2 provides the instructor with a repeat indication of the aircraft barometric height displayed on the co-pilot's altimeter AB/AD.

Airspeed indicator

133. Airspeed indicator /M1 repeats the indications of the pilot's ASI instrument AA/AD.

GCA bearing indicator

134. The GCA bearing indicator /X1 displays the aircraft-to-GCA station bearing.

ATMOSPHERE PANEL 22AG

Airfield height potentiometer

135. The AIRFIELD HEIGHT potentiometer /RV1 enables the instructor to set the height of the selected airfield between 0 and 10 000 ft.

Pressure potentiometer

136. The PRESSURE potentiometer /RV2 enables the instructor to set the barometric pressure at sea level from 29 to 31in Hg.

Wind speed potentiometer

137. The WIND SPEED KNOTS potentiometer /RV3 enables the instructor to adjust the windspeed between 0 and 150 knots.

Wind direction control

138. The WIND DIRECTION DEGREES control enables the instructor to set the wind direction through 360°.

CO-ORDINATE SETTING PANEL 21AA

Northings and eastings potentiometers

139. The SET SMALL AREA DATUM N (northings) and E (eastings) potentiometers, /RV2a and /RV1a respectively, enable the instructor to set the small-area chart datum to any required position within the large-area chart.

Null selector

140. The NULL SELECTOR switch /S2 provides selection of the co-ordinates (as set by the respective N and E potentiometers (para.139, 149 and 151)) of any one of the eight stations, and of the small-area chart datum, enabling the instructor to accurately position the selected station site on the large-area and small-area charts, and to position the small-area chart datum relative to the large chart by means of the N and E null indicators (para.143).

Warning lamp

141. The warning red-coloured lamp /LP1 is lit when the NULL SELECTOR switch /S2 (para.140) is not in the OFF position.

Small/large switch

142. The SMALL/LARGE switch /S1 provides selection of large-area or small-area chart co-ordinates for station positioning.

Northings and eastings null indicators

143. The N (northings) and E (eastings) null-indicators, /M1 and /M2 respectively, facilitate accurate positioning of any of the eight simulated ground stations to any required site on the charts, and the positioning of the small-area chart datum to any site within the large chart area. The stations are positioned by comparing the co-ordinates obtained from the respective chart, selected by switch /S1 (para.142), with those from the station N and E co-ordinate setting potentiometers (para.139, 149 and 151), and adjusting the station co-ordinates to obtain a null-reading.

STATION PANELS 21AC, AD, AE AND AF

144. The four station panel assemblies 22AC, AD, AE and AF are identical. Each panel contains frequency-setting switches, station co-ordinate setting potentiometers and indicators relative to two stations. The controls, switches and lamps relative to station 1 only, situated on the top half panel 21AC, are described.

OFF switch

145. The OFF switch /S9 enables the instructor to switch off station 1.

In use lamp

146. The IN USE lamp /LP1 is lit when any one of the four aircraft navigational receivers is tuned to station 1 (provided that station 1 is switched on).

Station frequency-selection switch

147. The STATION FREQUENCY selection switch /S7 selects station 1 frequency.

Mc/s - kc/s switch

148. The MC/S - KC/S switch /S5 selects the frequency band available to /S7 (para.147). The function and frequency allocated to the station can be written in pencil on an ivorine writing pad adjacent to /S5.

N and E potentiometers (large-area chart)

149. The LARGE AREA N and E (northings and eastings) potentiometers, /RV7 and /RV5 respectively, enable the instructor to position the station to any site within the area of the large chart, provided that the chart selection switch /S1 (para.150) is set to LARGE.

Large // large/small switch

150. When the LARGE // LARGE/SMALL switch /S1 is set to LARGE, the co-ordinates of the station and of the simulated aircraft (used in bearing computation) are obtained from the large-area chart irrespective of the relative positions of aircraft and charts. When /S1 is set to LARGE/SMALL, the co-ordinates of the station are obtained from the small-area chart when the aircraft position lies inside the small chart limits, or from the large-area chart when outside small chart limits.

N and E potentiometers (small-area chart)

151. The SMALL AREA N and E (northings and eastings) potentiometers, /RV3 and /RV1 respectively, enable the instructor to position the station to any site within the small-area chart, provided that /S1 (para.150) is set to LARGE/SMALL and that the small-area chart pen is not at its limits.

AUDIO DRAWER 21AG (TOP AND FRONT)

Recording level indicator

152. The recording level indicator /M1 enables the instructor to monitor the tape-recorder recording level. To obtain recordings with the minimum of distortion the level indication should be maintained at or below the unity calibration on the meter scale.

Frequency selector switch

153. The FREQUENCY SELECTOR switch /S25 enables the instructor to select the output of any one of the four oscillators that provide radio aids coded idents.

Track selector switch

154. The TRACK SELECTOR switch /S23 enables the instructor to select any one of sixteen tracks corresponding to eight simulated station idents, three ILS markers, and five FAN markers, for the purpose of recording, monitoring, or erasing.

Tape position indicator

155. The TAPE POSITION indicator registers the time elapsed from starting the tape transport mechanism.

Morse key

156. The morse key /S21 is used when recording coded idents; this is a standard key provided with a "lock-open" slide-control which prevents accidental operation of the key when the slide-control is set to R; when the slide-control is in the S position, the key can be operated.

Off/ready/record switch

157. The OFF/READY/RECORD switch /S22 has the following functions:

(1) OFF. The output of a selected replay amplifier is routed to the instructor's headset for monitoring purposes.

(2) READY. The output of the recording amplifier is routed to the instructor's headset, enabling him to check the operation of ident oscillators and of his microphone without actually recording. The track selector switch /S23 (para. 154) may be operated with /S22 in this position to pre-select a track for recording.
(3) RECORD. Full recording and erase facilities available, with sidetone fed to the instructor's headset.

Morse/voice switch

158. The MORSE/VOICE switch /S24 enables coded or voice idents to be recorded onto a selected track.

Off/on switch

159. The OFF/ON switch /S26, when operated to the ON position, applies power to the pinch-roller solenoid, and to the tape position indicator.

Static volume potentiometers

160. The STATIC VOLUME potentiometers: MF PRECIPITATION (/RV5), MF CRASH (/RV4) and VHF (/RV3) enable the instructor to adjust the level of static noise introduced to the VHF and MF audio systems. The HF potentiometer (/RV2) is fitted but is not functional.

Marker volume potentiometer

161. The MARKER VOLUME potentiometer /RV1 controls the volume level of marker idents. Switch /S1, which is coupled to the shaft of /RV1, operates at the half-volume position, thus preventing the operation of the pilot's, co-pilot's and instructor's marker lamps below the half-volume level.

Fans switch

162. The FANS switch /S2 provides selection of audio idents of the Z-marker, inner-, middle- and outer-markers, and of five FAN markers.

Stations/fans switch

163. The STATIONS/FANS switch /S4 enables the instructor to monitor any of the 16 tracks of the tape recorder.

ILS markers auto/manual switch

164. The ILS MARKERS AUTO/MANUAL switch /S3 enables the ILS outer- and middle-marker idents to be controlled automatically by the ILS/VOR system when /S3 is set to AUTO, or by the instructor when /S3 is set to MANUAL.

OM and MM fail switches

165. The OM (outer marker) and MM (middle marker) FAIL switches, /S27 and /S28 respectively, enable the instructor to fail the automatic operation of the middle- and outer-marker audio and visual idents; the respective marker indicator lamps in the cockpit and or panel 24AB (para.95 and 96) are extinguished when /S27 and/or S28 is set to FAIL.

BFO No.1 and No.2 lamps

166. The ADF BFO No.1 and No.2 lamps /LP1 and /LP2 light when the appropriate ADF BFO switch, CF/AC and/or CF/AD, in the cockpit is operated.

Stations 1 to 8 fail switches

167. Operation of any of the eight STN 1 to 8 FAIL switches, /S12 to /S5 inclusive, simulates audio failure of the associated ground station.

Receiver selectors switches

168. The five RECEIVER SELECTORS switches /S14 to /S18, inclusive, when used in conjunction with the MICROPHONE SELECTOR switch (para.170), enable the instructor to monitor the following facilities:

(1) VHF 1 (/S18) - VHF COMM 1 audio
(2) VHF 2 (/S17) - VHF COMM 2 audio
(3) HF (/S16) - not used
(4) I/C (/S15) - intercom (interphone)
(5) MKRS (/S14) - marker audio.

Private line lamp

169. When lit, the PRIVATE LINE lamp /LP3 indicates that the flight instructor wishes to communicate with the console instructor via the private line.

Microphone selector switch

170. The MICROPHONE SELECTOR switch /S13, when used in conjunction with the RECEIVER SELECTORS switches (para. 168), enables the instructor to participate in the following audio systems:

(1)	switch position I/C	-	intercom (interphone)
(2)	switch position VHF 1	-	VHF COMM 1 audio
(3)	switch position VHF 2	-	VHF COMM 2 audio
(4)	switch position HF	-	not used
(5)	switch position PRIVATE	-	instructors' private line.

PTT/LTT switch

171. The PTT/LTT (press-to-talk/lock-to-talk) switch, /S19, enables the console instructor to communicate with the flight instructor and with the crew.

Jack socket

172. Jack socket /JK1 provides the usual connection for the instructor's headset and microphone to the audio systems.

Microphone and headphone volume potentiometers

173. The MICROPHONE and HEADPHONE VOLUME potentiometers, /RV6 and /RV7 respectively, enable the instructor to control the volume level of his microphone and headphone.

TAPE RECORDER CONTROLS (REAR OF AUDIO DRAWER)

Mains/on switch

174. The MAINS/ON switch connects the mains 45/65c/s power supply to the tape recorder unit.

WARNING...

WHEN OPERATING THE SIMULATOR FOR PROLONGED PERIODS WITHOUT USING THE TAPE RECORDER, THE MAINS/ON SWITCH MUST BE SET TO OFF TO PREVENT DAMAGE TO THE STATIONARY TAPE BY THE REVOLVING CAPSTAN. WHEN THE SWITCH IS SELECTED 'ON', THE ADJACENT NEON INDICATOR IS LIT.

Tape speed switch

175. The TAPE SPEED INCHES/SEC switch enables the tape speed to be set to either $7\frac{1}{2}$ or 15(in/s); normally this switch is set to $7\frac{1}{2}$. The adjacent neon lamps indicate, when lit, the selected tape-speed.

Start, record and stop switches

176. The START, RECORD and STOP push-button switches are fitted but are not functional; the tape recorder is remotely controlled by switches on the top panel of the audio drawer (para. 152). The neon indicator adjacent to the RECORD switch is also non-functional.

Remote stop switch

177. The REMOTE STOP switch must be set to the IN position.

Sync. control switch

178. The SYNC. CONTROL switch has no function and should be set to the centre "off" position.

PART 3

ELECTRICAL POWER SUPPLIES

Chapter 1

EXTERNAL POWER SUPPLIES

List of Contents

List of Illustrations

General

1. The electrical power units of the flight simulator are contained within the simulator installation and are fed from three-phase supplies of 110 to 120V (nominal 208V between phases), 45 to 65c/s. The supplies are stepped-up to 400V (between phases), and are connected via a mains regulator to power rack 11 for switching, fusing and distribution. This a.c. supply feeds all the power units of the flight simulator and the separate power units of the radio aids supplies. A.C. power for the hydraulic system is fed directly from the wall supplies to the hydraulic power pack

<u>Mains switching</u> (/501)

2. Total power requirements of the flight simulator are 30kVA (maximum). This power is supplied from a suitable three-phase (wall-located) supply point of 110 to 120V, 45 to 65c/s. A separate (local) earth point is also required. Each phase of the wall supply is individually fused and switched by independent mains-isolation switches as follows:

(1) SIMULATOR switch connects the three-phase supplies to the flight simulator.

(2) HYDRAULICS switch supplies the three-phase supplies to the hydraulic power pack of the motion and control loading units (C L U) systems.
(3) SERVICE switch supplies a single phase (phase A) to the servicing sockets within the area of the simulator.

Auxiliary units

3. Auxiliary electrical units and power units, not of G.P.S. manufacture, are listed in Chap.2. The auxiliary units include the Foster step-up transformer and the Foster mains regulator units; the step-up transformer also provides isolation of the mains supply.

4. The step-up transformer is fed with the mains supply from the SIMULATOR switch (para.2); its secondary-winding supplies 400V (between phases), 45 to 65 cycles, to the a.c. regulator unit. The regulator unit stabilizes the stepped-up, isolated, a.c. supply and is capable of suppression of mains voltage fluctuations up to 10 per cent (maximum); the unit delivers a three-phase output of 230V a.c. ± 1 per cent (with respect to neutral) at 21kVA (maximum), with a speed of correction of 1 per cent per second.

5. The stabilized three-phase output of the regulator unit is fed to power rack 11 for distribution in the flight simulator power systems (Chap.3).

Chapter 2

AUXILIARY POWER EQUIPMENT

List of Contents

General

1. The auxiliary power equipment, which is used in the simulator power systems, comprises items of electrical equipment which are not of G.P.S. manufacture and which are not described in this publication. In most instances the description, setting-up procedures, operating and servicing instructions are provided by the equipment manufacturer, and the respective publication will be issued with the simulator under a separate cover. The following text includes a brief description of each auxiliary power unit, together with (where applicable) the specification, type, manufacture and application in the simulator circuit.

Auxiliary units

2. The auxiliary units comprise:

(1) Three-phase step-up transformer, Foster, 208V to 400V line-to-line, with a power rating of 21kVA at 45 to 65c/s.. This unit is included in the mains supply circuit between the mains isolation switch and the voltage regulator (Chap.1).

(2) Voltage regulator, Foster, type VR/TOR, with a stabilized three-phase a.c. output of 230V ± 1 per cent per phase. This unit, which is capable of absorbing mains variations of 10 per cent, is rated at 21kVA. In the flight simulator, the voltage regulator unit stabilizes the output of the step-up transformer (Chap.1).

(3) Motor-alternator, Mackie, incorporating star-delta starter, type ZSD, and transistorized frequency regulator, type TR1812, which controls the alternator exciter windings. The output of the alternator is 200V, 400c/s; this voltage is transformed, by a conventional Scott circuit , into a reference and quadrature supply of 115V, 400c/s and 26V, 400c/s, respectively. The outputs of the transformers supply synchros and synchro-resolvers in the chart systems and in the radio aids systems (power distribution, Chap.3).

(4) ±300V d.c. unregulated power unit, A.T.P., type 12045; this unit is capable of supplying ±300V at 5A to power output stages (usually cascode-connected pairs of valves) of standard d.c. amplifiers.

(5) +28V d.c. unregulated power unit, Coutant, type R 53000, which delivers +28V at 30A for energizing relays and other circuits operating from unregulated supplies.

(6) -28V d.c. unregulated power unit, Coutant, type D1000, which supplies -28V at 10A to motor windings, etc.

(7) -28V d.c. regulated power unit, Advance, type DC 13, which supplies -28V at 5A to the transistorized amplifiers of the audio system (Part 12, Chap.5).

(8) +28V d.c. regulated power unit, Coutant, type ES 100/28, which supplies +28V at 1A (maximum) to the digital boards of the radio aids systems (Part 12).

(9) -28V d.c. regulated power unit, Coutant, type ES 1000/28, which delivers -28V at 10A (maximum) to the digital boards of the radio aids systems (Part 12).

(10) +12V, +6V d.c. regulated dual power unit, Coutant, type ED 100 12/6 which is capable of supplying +12V at 1A and +6V at 1A to the digital boards of the radio aids systems (Part 12).

(11) -12V d.c. regulated power unit, Coutant, type ES 300/12 which supplies -12V at 3A to the digital boards of the radio aids systems (Part 12).

Chapter 3

POWER SUPPLY SYSTEMS AND POWER DISTRIBUTION

List of Contents

List of Illustrations

General

1. The isolated and stepped-up three-phase supplies from the main regulator (Chap.1) are fed to rack 11 for switching and distribution to the flight simulator power circuits. The switching of the a.c. supplies is controlled from the mains control panel (11C); the required fuses and visual indicators are fitted on the adjacent fuse and indicator panel (11A). The power system includes a three-phase failure trip circuit that is connected in series with the heater trip circuits of each computer rack, and with two emergency STOP switches. The trip circuit ensures that the a.c. power to the simulator is cut-off if any of the rack heater supplies are overloaded, or if the emergency STOP switches are used; the three-phase failure circuit operates the trip circuit in the event of failure of one or more phases of the a.c. wall supplies.

A.C. POWER DISTRIBUTION (/500)

2. A.C. power to the simulator is controlled by the LT and HT START and STOP switches on panel 11C. The switches and the associated circuits are energized with phase 'A' supplied via the safety trip-circuit (para.22). The LT START and STOP switches control the instantaneous a.c. supplies contactor 11X/CR1, mounted on side-panel 11X, which supplies the heater transformers of the power units on rack 11, both ventilating fans of rack 11, the heater transformers of racks 13 and 14, a.c. power to the fuselage, and the radio aids fuse and switch panel on rack 24. The HT START and STOP switches control the delayed a.c. supplies contactor /CR2 (panel 11X) which operates with an automatic delay and connects the a.c. supplies to the h.t. transformers of the power units on rack 11, the transformers of the three-phase failure circuit (para.23), the ±300V unregulated power unit (11F), and the ±28V power units at the rear of rack 11 (11BA, 11BB respectively).

3. The side recess of rack 11 is fitted with a number of terminal strips for distribution of the power supplies. Situated at the lower half of the recess is the central earth point (C.E.P., /501) at which the signal and other earth returns are connected to the local, external, earth. The two contactors /CR1 (instantaneous a.c.) and /CR2 (delayed a.c.) are located at the bottom of the recess. A panel, mounted in the forward part of the side recess, is fitted with fuses 11X/F1, /F2 and /F3 that supply the instantaneous a.c. power to the radio aids console, and fuses 11X/F4, /F5 and /F6 which are in the circuit of MAINS ON lamps 11A/LP11, /LP9 and /LP7; these lamps indicate the availability of the a.c. supplies to rack 11. The function of fuses /F4, 5 and 6 is to protect the a.c. wiring in case of failure of the lamps or capacitors 11X/C1, /C2 and /C3 which are connected in parallel with the lamps; these capacitors by-pass transient disturbances on the a.c. supply lines to the neutral line, and, via capacitor 11X/C4, to the local earth line. Resistors 11X/R1, /R2, and /R3 are located on the inner face of panel 11X and are connected in series with the RADIO AIDS lamps 11A/LP6, /LP8 and /LP10 on panel 11A.

Mains control panel

4. The mains control panel (11C) is a standard unit and is described in Part 5. The unit contains the LT and HT START and STOP push-buttons that control the operation of contactors 11X/CR1 and /CR2. The front panel contains the delayed a.c. supply HT ON neon indicator 11C/V1 and hour-meter /M1. The three-phase failure safety-interlock circuit (para.23) is fitted on the chassis of this unit.

Fuse and indicator panel

General

5. The fuse and indicator panel 11A is a non-standard unit and is mounted on rack 11. It contains, on its front panel, 11 lamps and 19 fuses fitted with integral failure lamps. The fuses and indicators provide protection and indication, respectively, in the event of malfunction in the following circuits:

(1) Failure of the main a.c. supply to rack 11
(2) Open-circuited trip-circuit supply to the mains control panel
(3) Failure of any individual instantaneous a.c. supply to the simulator racks
(4) Failure of any individual delayed a.c. supply to rack 11.

Circuit description

6. Three MAINS ON indicator lamps on panel 11A are lit when the a.c. supply is connected to the inputs of rack 11. Five neon indicators operate in a safety-trip circuit, and a further three indicator lamps are lit when the three associated fuses on panel 11X are ruptured. The 19 fuses are provided with integral indicator lamps that light when failure of the associated fuse(s) occurs.

7. The three MAINS ON indicator lamps 11A/LP7, /LP9 and /LP11 are lit via fuses (11X/F4, /F5 and /F6), when the three-phase a.c. supplies from the main regulator unit are connected to the inputs of rack 11. The fuses are mounted on panel 11X in the side recess of rack 11. Failure of a fuse, or of the respective phase, will extinguish the appropriate indicator lamp.

8. The trip-circuit (para.22 and 23) of the a.c. supplies to rack 11 is energized by the red phase (A) which supplies the contactors (11X/CR1 and /CR2 respectively) of the instantaneous and delayed a.c. supply-circuit via the completed trip-circuit through all the racks. When any one of the computer-rack heater-circuit trip switches is actuated, or when one of the emergency STOP buttons is operated, the

associated neon indicator (11A/LP1, /LP2, /LP3, /LP4 and /LP5), on panel 11A, is lit, and the instantaneous and delayed a.c. supplies are automatically disconnected. The trip-circuit is protected by fuse 11A/F1; the integral indicator is lit when /F1 is ruptured.

9. Eight fuses and associated indicator lamps and three RADIO AIDS indicator lamps (11A/LP6, /LP8 and /LP10), for the radio aids fuses mounted on panel 11X, are connected to the instantaneous a.c. supply circuits from contactor 11X/CR1; these fuses and lamps are located in the INSTANTANEOUS MAINS group of fuses and lamps. Each indicator lamp lights when its corresponding fuse is open-circuited.

10. The "red" phase ('A') is fed to rack 14 and to the top fan of rack 11 via fuses 11A/F6 and /F5,respectively, and the associated fuse-fail indicators. The "white" phase ('B') is supplied to rack 13, to the fuselage and to the bottom fan of rack 11 via fuses and indicators, 11A/F12, /F11 and /F10. The "blue" phase ('C') is fed to the heater-transformers of voltage regulators VR22G (11D) and VR28A (11E) via fuses and indicators, 11A/F18 and /F17.

11. Ten DELAYED MAINS fuses and associated fuse-fail indicators are connected in the delayed a.c. supply circuits, fed from contactor 11X/CR2.

12. Three phases of the delayed a.c. supply are routed from contactor 11X/CR2 via fuses 11A/F4, /F9 and /F16 to the primaries of transformers 11C/T1, /T2 and /T3 respectively. The transformers form part of the phase-failure protection circuit which is included on the mains control panel (Part 5) and which is described in para.23. A three-phase supply to the ±300V unregulated supply unit (11F) is fused by 11A/F3, /F8 and /F15.

13. A single-phase ("red") supplies the +28V power unit, 11BA, via fuse 11A/F2; the supply to the -28V power unit, 11BB, is fed, via fuse 11A/F7, from the "white" phase. The "blue" phase is routed to the h.t. transformers in voltage regulators VR22G and VR28A, via fuses 11A/F14 and /F13 respectively.

<u>FLIGHT COMPUTER D.C. POWER DISTRIBUTION</u> (/501)

14. Instantaneous a.c. power from contactor 11X/CR1, and delayed a.c. power from contactor 11X/CR2 (para.2) are fed via the fuse and indicator panel 11A to the power units, on rack 11, which supply the flight and engine computers. The following power units are positioned on rack 11:

(1) ±300V regulated power supply unit 11D which consist of voltage regulator type 22G described in Part 5; the type 22G unit provides three stabilised power outputs of ±300V at 1A and -500V reference voltage at 8mA for general use in the computing circuits.

(2) ±50V regulated power supply unit in position 11E; this unit consists of voltage regulator type 28A described in Part 5. The high-stability ±50V outputs are used as signal voltages to the computing circuits of the flight and engine computers.
(3) ±300V unregulated power unit, A.T.P. model 12045, in position 11BA, which supplies d.c. power to the output stages of the d.c. amplifiers.
(4) ±28V power unit, Coutant type RS 3000 in position 11BA, which provides general d.c. supplies to relays, motors, etc.
(5) -28V power unit, Coutant type D 1000, in position 11BB, which supplies general d.c. supplies to motors, etc.

15. The power units on rack 11 supply the required d.c. power only to the racks of the flight and engine computers. A.C. and d.c. power to racks 13 and 14 is supplied via the appropriate inter-rack connecting looms which terminate at the computer rack distribution panel. This panel is fitted with individual LT and HT switches and relays that isolate the incoming supplies from the rack wiring. The rack power distribution system is described in para.17 to 20 inclusive. Rack 12 is not used and the wiring to rack 12 (diagram /500) is not incorporated.

Voltage calibrator

16. The accuracy of the d.c. voltages exceeding ±50V is established by use of the voltage calibrator type 6A in position 11B. The calibrator, which is a standard unit described in Part 5, contains a voltage selector, galvanometer and voltage discriminating circuit by which the measured voltage is compared against a fixed reference; thus the calibrator provides accurate voltage measurements for setting the outputs of the relevant power units.

Standard computer rack power distribution (/502)

17. The incoming power supplies are routed to the computer rack distribution panel situated at the base of each of the engine and flight computer racks. The panel is fitted with the LT and HT switches, fuses and indicators, thermal overload cut-out switches of the heater supply and trip circuit, and the h.t. switching circuits. The relays are mounted on a chassis positioned behind the panel; two rack heater transformers are located in the base of the rack. The bottom and top fans of each rack operate as soon as the instantaneous a.c. supplies are switched on at rack 11. Each fan supply line is individually fused.

18. Power and signal voltage return lines, and supply lines carrying low-tension d.c. voltages (±50V or less) are directly connected to the rack circuits and are

controlled only from the mains control panel on rack 11. D.C. voltages exceeding 50V, and all a.c., 400c/s, supplies are switched by contact sets of delayed-operation relays which operate when the HT switch is set to ON.

19. The instantaneous a.c. supplies from rack 11 are connected to the LT switch HS/S2 and, via fuses HS/F4 and /F7, to the top and bottom fan motors (X/X1 and /X2) respectively. The indicator lamp, associated with the respective fuse, lights when the fuse ruptures. When the LT switch, HS/S2, is set to ON, the instantaneous a.c. supply is fed to the LT ON neon indicator HS/V2, and to heater transformers TR1 and TR2, via the corresponding thermal over-load cut-out switches, HS/RL1 and /RL2. The transformers secondaries supply the heaters of all valves in the rack. The heater supply from transformer TR1 is at earth potential; transformer TR2 output is at the -300V d.c. potential. The thermal switches, HS/RL1 and /RL2 are in the safety trip circuit (para.22); the contact sets of these switches are normally made. In the event of a short-circuit in the heater supplies, the solenoids of the switches operate and open-circuit the trip circuit; this, in turn, releases both a.c. supplies contactors on rack 11, and power to the simulator is disconnected. When the LT switch is set to ON, the HT switch HS/S1 is armed and, when made, it supplies a.c. voltage to the automatic h.t. delay circuits. The delay circuit is supplied via released contact set HS/RL3/2 which connects the a.c. supply to the coil of thermal delay relay HS/RL4. The contact set of this relay makes after a delay of approximately one minute; the energizing supply operates relays HS/RL3, /RL5 /RL6, and the HT ON lamp HS/V1 lights. Operated contact set HS/RL3/1 provides a holding circuit for the relay coils; simultaneously, thermal delay relay HS/RL4 is released by operated contact set HS/RL3/2. The five contact sets of relay HS/RL4 connect the -500V and ±300 regulated and unregulated supplies to the rack. Similarly, the three contact sets of relay HS/RL6 connect the a.c., 400c/s, supplies to the rack.

20. Fuses and associated indicator lamps are inserted in the unregulated h.t., ±28V, and a.c., 400c/s, supply lines. A spare input line, fitted with a fuse and indicator lamp, is included in each rack. Each indicator lamp lights when the corresponding fuse ruptures.

Trip circuit (/500, /502)

21. The function of the trip circuit is to disconnect the a.c. supplies from power rack 11 in the instance of:

(1) Overloading of the heater transformers on racks 13 and 14
(2) Operation of the emergency STOP switches on the console or in the fuselage
(3) Failure of one or more phases of the a.c. supplies from the mains regulator.

22. The trip circuit is separately fused by fuse 11A/F1 (/500) which, together with the associated indicator lamp, is mounted on the fuse and indicator panel 11A. The circuit is fed with phase 'A' and includes series-connected console and fuselage emergency STOP switches, contacts of the heater-overload relays of each computer rack (para.19), the contact of the phase-failure protection relay (para.23) and the circuits of the LT and HT START and STOP switches on the mains control panel. When any of the contact sets or the STOP switches are operated, the trip circuit is broken and power is not available to the LT and HT START switches. The two main contactors (11X/CR1 and /CR2) are released and the three-phase supplies to the computer racks and to the radio aids console are disconnected. The console and fuselage STOP switches and the contact sets of the rack heater supply overload relays are each fitted with warning lamps which, when lit, indicate the location of the open-circuit; all these lamps are positioned on the TRIP section of the fuse and indicator panel 11A.

Three-phase failure trip circuit

23. The three-phase failure circuit forms a part of the simulator trip circuit; the associated components are included on the chassis of the mains control panel (11C). The circuit consists of three transformers that are fed with the respective three phases and connected in a star circuit. The secondaries of the three transformers are series-connected and supply the heating element of the thermal overload cut-out switch 11C/X2. If all three phases are present, the resulting heater element voltage is 0V; if one or two phases ('B' and/or 'C') fail, the resulting increased secondary voltage will supply the heater element, and the adjacent trip switch will open-circuit the simulator trip circuit, thus disconnecting all power to the simulator.

RADIO AIDS POWER SUPPLIES (/340)

24. The d.c. and a.c. power for the simulator radio aids computing circuits is derived from separate power units and from a motor-alternator via the simulator a.c. supplies switching circuits (contactor 11X/CR1). The radio aids power supplies consist of the following:

(1) D.C. supplies:

(a) ±250V d.c. unregulated power unit, in position 24BF, which supplies h.t. to the a.c. amplifiers of the radio aids and chart recorder systems (Part 12)

(b) +28V d.c. unregulated power unit, in position 24BF, which provides the general d.c. supply for the operation of relays, motors, etc.

(c) -28V d.c. regulated power unit, Advance type DC 13 which supplies the transistorized amplifiers of the audio system (Part 12)
(d) Digital boards (Part 12) power supplies in position 26BF:

(i) -28V d.c. regulated power unit, Coutant type ES 1000/28
(ii) +28V d.c. regulated power unit, Coutant type ES 100 /28
(iii) -12V d.c. regulated power unit, Coutant type ES 300 /12
(iv) +12V, +6V dual d.c. regulated power unit, Coutant type ED 100 12/6.

(2) A.C. supplies:

(a) 6·3V a.c. heater supplies which consist of two sets of transformers (No. 1 and No. 2 heaters in positions 22BE and 24BF respectively) each with two secondary windings; the two 6·3V outputs of transformer 22BE/T1 are at earth potential, and one 6·3V output of transformer 24BF/T3 is at -250V d.c; the second 6·3V output of /T3 is spare.
(b) A.C. supplies for the digital indicators type DM160, which are fitted on the state panel in position 21BB; the indicator supplies consist of transformer 26BF/T1 which provides the following two secondary outputs:

(i) 35V a.c. h.t. supply
(ii) 1V a.c. heater supply.

(c) A.C. supplies at 400c/s which are provided by the Mackie motor-alternator; the motor-alternator is a self-contained unit equipped with a three-phase starter type ZSD and an automatic voltage regulator. The output of the unit is 200V a.c., 400c/s; this output is transformed to 115V via transformers 25BF/T1 and /T2 which are Scott-connected to provide an additional quadrature phase at 115V, 400c/s. The two transformers also supply a 400c/s amplifier which delivers 40V, 400c/s. The 400c/s supplies are described in para.31 to 33 inclusive.

D.C. power supplies (/340)

25. Three-phase power for the radio aids is supplied via the instantaneous mains contactor 11X/CR1 (para.2). The transformer-derived supplies are controlled from the fuse and switch panel 24BE; the motor-alternator is controlled by the HT START and STOP switches (para.2).

26. The radio aids fuse and switch panel is a standard unit described in Part 5. The panel is fitted with LT and HT ON/OFF switches, 24BE/S1 and 24BE/S2 respectively, and with fuses and corresponding indicator lamps arranged in two

groups consisting of five fuses for the D.C. SUPPLIES, and three A.C. 400C/S SUPPLIES fuses. When operated, LT switch /S1 supplies the respective phases to the primaries of the heater transformers. The secondaries of transformers 24BF/T3 and 22BE/T1 supply the valve heaters in their respective racks and also supply delay circuits consisting of delay switches 24BE/X1 and /X2. The heating elements of the delay switches are fed via released No. 2 contact sets of relays 24BE/RL1 and /RL2. After a delay of approximately one minute, the contacts of the heated bimetallic strips make and energize their respective "h.t. ready" relays (/RL1 and /RL2). The operated No. 2 contact sets disconnect the heating elements and maintain the relays energized. The operated No. 1 contact sets of these relays, together with No. 1 contact set of the "simulator h.t. on" relay 24BE/RL3, complete the circuit of phase 'A' via the LT switch to the transformers (24BF/T1 and T2) of the ±250V power unit.

27. The coil of relay /RL3 is energized via the HT START switch on panel 11C and the HT switch 24BE/S2. Operated contact set /RL3/2 energizes the primary of the +28V d.c. power unit transformer 24BF/T4 with phase 'B', and operated contact set /RL3/3 similarly connects phase 'C' to the four digital boards power units, to the -28V d.c. Advance power unit and to the 35V, 1V transformer, 26BF/T1.

±250V, +28V power units (C99138/01)

28. The h.t. supplies for the a.c. amplifiers of the chart and radio aids systems are provided by the unregulated ±250V, 2·5A, supplies (in position 24BF) which are produced by rectification and smoothing of the secondary output of transformers T1 and T2. These positive and negative supplies are derived from identical circuits which are contained on separate sub-chassis of unit 24BF. Each circuit consists of the mains transformer, a bridge-rectifier (MR1 to MR4 in the -250V unit) and a pair of smoothing capacitors (C3a and C3b). Mains transients are suppressed by a capacitor/resistor network (C1 and R1); internal loading is provided by resistor R3.

29. The +28V, 10A, power unit, also in position 24BF, consists of transformer T4, bridge-rectifier MR9 to MR12, inclusive, four parallel-connected smoothing capacitors C5a to C5d, inclusive, and load resistor R5.

30. Transformer T3 provides the No. 2 heater supplies.

<u>400c/s supplies</u> (/341)

31. The 400c/s supplies are required for the synchro-resolver circuits of the radio aids, chart recorder systems, etc. The 400c/s supplies from the Mackie 400c/s motor-alternator are transformed in a Scott circuit, (C99142/01), by

transformers T1 and T2 which produce two phases at 115V and a quadrature 115V reference phase. Transformer T3, delivers 26V, 400c/s. The bearing accuracy of the bearing resolvers system requires a pure sine waveform, at 40V, 400c/s, which is produced by 400c/s amplifier X1; the 400c/s supplies (/341) consist of the following:

(1) Three-phase 200V outputs
(2) Two anti-phase (ϕ_1 and ϕ_2) and quadrature (ϕ_{Ref}) outputs at 115V
(3) A single-phase 26V (ϕ_2) output
(4) Two anti-phase 40V (ϕ_A and ϕ_B) outputs.

Motor-alternator (/341)

32. The a.c. supplies from the step-up transformer (Chap.1) are routed to the Mackie motor-alternator via a fuse and isolator box which contains a mains isolation switch and three additional fuses. The isolation box is connected to a type ZSD star-delta starter unit, which is controlled by the No.2 contacts of the simulator HT START and STOP push-button switches on panel 11C. This switching arrangement ensures that the alternator is running and is ready for use even if the radio aids power supplies are not switched on. The motor is coupled to the exciter and alternator by a gear, and a belt and pulley, drive. To enable the motor-alternator to operate from 50 or 60c/s, the appropriate gearwheel must be selected as follows:

(1) 40 teeth gearwheel for 50c/s supply
(2) 48 teeth gearwheel for 60c/s supply.

33. The motor speed is governed by the d.c.-fed exciter winding to maintain the output constant at 400c/s. The exciter control voltage is derived from an integral, transistorized, voltage regulator which senses the variations of the alternator output voltage. The alternator output of 200V, 400c/s (at 1kVA maximum), is fused at 3A and is supplied to a pair of Scott-connected transformers (25BF/T1 and /T2) to provide the 115V outputs (para.31). A third transformer (/T3) delivers the 26V, 400c/s, output.

PART 4

MOTION SYSTEM AND HYDRAULIC SYSTEM

Chapter 1

COCKPIT MOTION MECHANISM AND HYDRAULIC POWER SUPPLY SYSTEMS

List of Contents

List of Illustrations

Introduction

1. The hydraulically-powered cockpit-motion system enables the crew of the flight simulator to experience sensory effects that are representative of those created by the motion of the aircraft.

2. The fuselage section (Part 1, Chap.2) of the simulator is mounted on a platform that is supported by three long-travel hydraulic jacks. Operation of the jacks is controlled, primarily, by electrical signals that originate in the flight computer; the electrical signals energize double-solenoid valves that control the flow of hydraulic fluid to the jacks. The jacks can operate differentially, or in unison, to represent the pitching, rolling or vertical movement of the simulated aircraft. The motion system is capable of reproducing the effects of atmospheric turbulence, high- and low-speed buffeting, and taxying.

3. Hydraulic power for the motion system is supplied by a self-contained hydraulic power pack which has a sufficient reserve of power to counteract any additional loading of the motion platform due to extra equipment, or increased number of instructors or observers. The power pack also supplies the artificial-feel units of the control-loading system (Part 9, Chap.1).

4. Electric power for the hydraulic power supply unit is routed, independently of the simulator supply, from a three-phase power point to a motor starter panel; this panel is mounted on the hydraulic power pack and controls the supply to the pump motor. The pump motor can also be controlled remotely from the motion control panel (mounted adjacent to the simulator). In an emergency, the pump motor can be switched off from a control on the flight instructor's panel in the fuselage, but the motor cannot then be re-started from this panel. To re-start the motor, it is necessary to operate the start button on either the hydraulic power pack or on the motion control panel.

MOTION MECHANISM

5. The motion mechanism comprises a movable platform, two stabilizing frames and three, vertically-acting, long-travel hydraulic jacks; the complete mechanism is mounted on a rectangular base structure which is secured to the floor of the simulator room. The platform is supported, above the base structure, on the three jacks; two of the jacks are located at approximately the mid-position of the sides of the base and the platform, the third jack being centrally mounted at the rear. Universal couplings are fitted to each end of the jacks to permit the required degree of angular movement. To prevent sideways, fore-and-aft, or rotational movement of the platform, relative to the base structure two stabilizing frames (one is A-shaped; the other is T-shaped) are interposed between the platform and the base structure. The legs of the A-frame are pivoted in bearings at the front corners of the base structure, and the apex of the A-frame is secured to a universal coupling at the centre of the rear of the platform. The cross-piece of the T-frame is located in bearings situated just aft of the side jack-mountings in the base structure; the tail of the T-frame passes between the legs of the A-frame and is secured to a universal coupling which is free to slide fore-and-aft in a guide assembly located on the longitudinal axis of the base structure.

HYDRAULIC INSTALLATION (A206502/08)

6. The hydraulic power pack is a self-contained, floor standing unit which provides hydraulic pressure for the jacks of the cockpit motion system and of the control loading units (CLU). The unit is connected to the three jacks of the motion system by means of three flexible supply hoses and rigid pipes with self-sealing

couplings; a fourth supply line supplies hydraulic fluid to the jacks of the CLU system The CLU and motion system common (hydraulic fluid) return line is connected by similar hoses and pipes to the hydraulic-fluid reservoir header tank.

7. The structure of the hydraulic power pack consists of a steel, angular-section, partially-enclosed framework which contains the following components:

(1) A 50 Imperial gallon (60 U.S. gallon) reservoir for the hydraulic fluid.
(2) An a.c. motor-driven pump capable of providing hydraulic fluid at pressures up to 2000 lb/in^2, normal operating pressure being 1500 lb/in^2.
(3) A 4 Imperial gallon (4.8 U.S. gallon) accumulator, pre-pressurized with nitrogen at 750 lb/in^2, i.e., half the operating pressure; this nitrogen pre-pressure is registered on the pressure gauge when the pump motor is switched off. The accumulator damps out pressure fluctuations when variable pressure demands are made. The accumulator charging point is located on the right-hand side of the unit.
(4) An oil cooler unit which cools the low-pressure return-fluid from the jacks to the reservoir.
(5) A filter unit that is inserted in the return line to the reservoir.
(6) Electrically- and manually-operated hydraulic valves.
(7) A pressure gauge, motor starter panel and a fluid-contents sight-gauge. fitted on the front panel of the unit.

The maximum hydraulic pressure is controlled by a relief valve which can be set to any pressure from 1500 to 3000 lb/in^2; normally this valve is set to 1500 lb/in^2.

8. The hydraulic pump motor can be switched on and off locally by means of ON and OFF buttons located on the motor starter panel. The motor can also be switched on and off from the motion control box (Chap.2), and switched off by means of the HYDRAULICS STOP push-button XF/AH/S5, located on the fuselage instructor's console.

Motion system hydraulics

9. The pump delivers a restricted flow of fluid to the motion system via a "restricted flow" solenoid valve and three adjustable restrictors. This restricted flow is supplied automatically for the first 20 seconds after switching-on the motion system; the platform is thus raised to its normal operating-height at a reduced rate. Full flow is achieved via a "full flow" solenoid-valve which, when operated, by-passes the restrictors in the pressure lines to the motion system jacks.

10. Movement of the port, starboard and rear jacks is controlled by Dowty Moog servo valves. Relief valves are fitted in the supply lines to each end of the jacks

and are set to operate when the pressure exceeds 2000 lb/in^2. Solenoid-operated settling valves in each jack assembly allow the motion platform to settle at a controlled rate when the system is switched off. The settling-rate can be preset and locked by means of a manually-set flow control valve fitted in the return line from each jack cylinder to its settling valve. Two limit switches are fitted to each jack, one setting the upward limit of travel, and the other the downward limit. The limit switches break the chain of series-connected interlock switches in the motion drive system (Chap. 2), and thereby shut off the simulator motion system if any jack reaches either of these limits.

11. If a failure occurs in the hydraulic power supply, electrical supply or flight computer signals to the motion drive system, the settling valves automatically take control and slowly return the platform to its lowest position, with all three bottom-limit microswitches operated.

Control loading unit hydraulics

12. The three CLU artificial-feel jacks are supplied with hydraulic fluid via a single restrictor solenoid valve. When the solenoid of this valve is de-energized, a restricted flow of fluid is fed via a 3/4-inch bore pressure line to the Dowty Moog servo valve associated with each jack. The hydraulic fluid to each jack is filtered before being passed to the Dowty Moog servo valve. A 1-inch bore line connects the return fluid from each of the CLU jacks, via the Dowty Moog servo valves, to the common hydraulic return (para. 6). When energized, the restrictor solenoid (in the power unit), allows full flow of fluid to the CLU jacks.

Chapter 2

MOTION DRIVE SYSTEM

List of Contents

List of Tables

List of Illustrations

Introduction

1. The motion system is driven hydraulically and controlled electrically. Hydraulic power is obtained from the simulator hydraulic power system (Chap.1) which also supplies the control loading units (flying controls and control loading system, Part 9, Chap.1). The electrical circuit that controls the motion drive system comprises:

(1) The motion control panel (MCB), which contains relays and switches that control the starting and stopping sequences of the motion system, and which also includes potentiometers for manual control of the motion platform. Associated with the MCB circuit are limit microswitches (fitted to the jacks), and control switches mounted on the flight instructor's console panel XF/AH.

(2) A positional servo system which controls the movements of each of the jacks in response to signals from the flight computer, or, when under manual control, according to the settings of three potentiometers on the MCB.

(3) A buffet oscillator, the output of which is summed with the flight parameters that are fed to the servo controls of the right and left jacks. The platform can thus be vibrated to provide simulation of airframe buffeting.

MOTION CONTROL BOX CIRCUIT (/206)

2. When the motion system is not in use the three hydraulic jacks are retracted, with the settling valves open, the bottom limit microswitches open-circuited, and the hydraulic power supply off. When the green START button MCB/S5 is pressed, switch /S5b closes and allows the hydraulic power supply motor starter to be energized. The star-delta motor starter switches to the delta connection when the motor attains running speed, and also connects 115V, 60c/s to bridge rectifier MCB/MR1, /MR2, /MR3 and /MR4. The d.c. output of the bridge rectifier energizes the "pump motor on" relay MCB/RL7.

3. MCB/S5a, when operated, energizes the "motion available" relay MCB/RL1. Contact set MCB/RL6/2 by-passes the limit microswitches for the initial part of the starting sequence, and /RL1/1 provides self-hold for /RL1 when MCB/S5 is released.

4. To obtain full operating conditions, either the MCB MOTION switch MCB/S3/1, or the fuselage MOTION switch XF/AH/S7 (as selected by the MANUAL/FLIGHT switch MCB/S1), must now be operated. Operation of the selected MOTION switch connects +27V, via operated contact set /RL7/1, to the coils of MCB/RL2, /RL3, and /RL4, to the thermal delay relay /RL8, to the fuselage "motion on" amber lamp XF/AW, and /S2LP (RESTRICTED FLOW) via operated contact set /RL5/1 (para.7). The MOTION lamp MCB/S3LP is lit by operated MCB/S3/2.

5. Operated contact sets /RL2/1, /RL2/2 and /RL3/1 connect 115V, 60c/s to the solenoids of the settling valves, which then shut off the return line from each of the jacks. Operated contact set /RL3/2 causes the solenoid of the "restricted flow" valve to be energized from 115V, 60c/s to allow hydraulic fluid to flow to the jacks. The "full flow" valve, which by-passes the restrictors in the jack supply lines, is closed initially, and the jacks are, therefore, supplied with fluid at "restricted flow" rate to raise the platform to the neutral position.

6. Contact sets of MCB/RL4 connect the outputs of the three positional servo amplifiers to their respective Moog valves, and the jacks commence to extend under restricted flow to a neutral position (assuming zero inputs from the flight computer) or, when under manual control, to a position corresponding to the settings of the manual position potentiometers MCB/RV1, /RV2 and /RV3. These potentiometers can be used to check the functioning of the motion system.

7. Thermal delay relay MCB/RL8 operates approximately 20 (maximum 45) seconds after either the MCB or the fuselage MOTION switch is pressed, and then connects +27V to the coils of relays /RL5 and /RL6, which energize and hold-on via contact set /RL5/1. Contact set /RL5/2 opens, allowing the heater of /RL8 to cool and to release its contact set. The RESTRICTED FLOW switch lamp MCB/S2LP lights when /RL5/1 operates and the switch is pressed.

8. The RESTRICTED FLOW switch MCB/S2/1, normally closed, allows the "full flow" solenoid to be energized from 115V, 60c/s when contact set /RL6/1 makes. The "full flow" valve then opens allowing an unrestricted flow of hydraulic fluid to the motion system jacks. Restricted flow conditions can subsequently be obtained by operation of the RESTRICTED FLOW switch.

9. Released contact set /RL6/2 removes the by-pass connection from the limit microswitches, enabling the motion system to become inoperative in the event of any of the jack limits being exceeded.

10. The motion system can be switched off from the fuselage or from the control box MCB. Operation of either fuselage HYDRAULICS STOP button XF/AH/S5 or MCB STOP button MCB/S4 (yellow) breaks the holding circuit of the MCB relays and causes the motor starter to trip. The settling valves open and the three jacks settle at a rate determined by a manually-set restrictor in the return line from each jack. When all three jacks have reached their bottom limit, the motion platform is at rest and conditions are as described in para.2. The motion system can also be switched off by releasing the appropriate MOTION switch; the electrical and hydraulic circuit action is then as described, except that the pump motor remains running.

11. All the MCB relays except MCB/RL7 will de-energize if any of the limit micro-switches open due to excessive extension or retraction of any of the jacks. In such an event, the motor continues to run, and MCB/RL7, therefore, remains energized from the rectified 115V, 60c/s a.c. supply. To restart the system, it is necessary to press the MCB START button to re-energize /RL1, the limit switches being by-passed by released contact set /RL6/2.

POSITIONAL SERVO CONTROL CIRCUIT (/206 and /207)

12. Each of the three motion system hydraulic jacks is fitted with a Dowty Moog valve to control differentially the flow of fluid into each jack cylinder. The direction and rate of flow of fluid is proportional to the polarity and magnitude of the current through the solenoid of the Moog valve. Each Moog valve is controlled by a positional servo control circuit, the circuits for all three jacks being identical except for component references and input summing networks; only the servo control circuit associated with the rear jack (/206) is described.

13. Relays 13D/T2/RL20 and /RL11 are energized when the fuselage MOTION switch is operated, and contact set /RL20/1 connects the input of amplifier 13DJ/a to summing resistor 13D/T6/R3. When under manual control, /RL20 is released and the input to 13DJ/a is taken from the wiper of manual position potentiometer MCB/RV2, via 13D/T6/R4. Released contact set /RL11/1 connects the signal summing point to earth to prevent unwanted feedback of signals to the flight computer when the motion system is under manual control.

14. The output of 13DJ/a is limited by feedback diodes to positive and negative values determined by the settings of preset potentiometers /RV5 and /RV8. Potentiometer /RV5 allows the maximum amplifier output to be adjusted between the limits of -41V and -63V; the setting of /RV8 defines the positive limits between +41V and +63V. Both limits are normally set to give a maximum amplifier output of ±50V, these values giving full extension and retraction of the jack. Capacitor 13D/T6/C1 delays the output of 13DJ/a to simulate the normal response of the aircraft to movement of the output controls

15. The output of amplifier 13DJ /a is fed to the input of the positional servo amplifier 13DJ /b via resistor /R14. The voltage at the summing junction of 13DJ/b is balanced by the positional-feedback voltage derived from the wiper of the potentiometer fitted to the rear jack. Capacitor /C12 and resistor /R12, connected in parallel with positional feedback summing resistor /R11, provide a small amount of phase-advance to increase the frequency response of the amplifier. Capacitor /C13 renders the amplifier insensitive to 60c/s signals which may be picked up by the feedback loop connection.

16. The gain of 13DJ/b can be adjusted between the limits of 10 to 20 by preset potentiometer /RV16. This control determines the response rate of the drive circuit, and is set to give prompt and conclusive response of the jack to changes of input voltage.

17. Contact set MCB/RL4/1, operated when the motion system is first switched on, connects the output of amplifier 13DJ/b to the solenoid of the rear jack Moog valve via /R19. When released, contact set /RL4/1 connects /R13 across 13DJ/b, reducing considerably the amplifier gain during settling. The 115V, 400c/s supply is fed to the Moog valve solenoid, via /C17 and /R17 to reduce the effect of hysteresis (due to static friction) in the spool stage of the Moog valve.

Flight computer signals (/206 and /207)

18. A number of signals are fed to the servo controls of the motion system from the flight computer to produce changes in attitude of the motion platform. Variation of these signals may be due to changing aerodynamic conditions, or may be a direct result of movement of the aircraft controls. In addition, signals representing atmospheric turbulence, buffeting, and touchdown impact are fed to the motion system to provide realistic sensory effects.

19. Movement of the motion platform to simulate various flight attitudes is achieved by operation of the jacks as follows:

(1) Rolling motion is produced by differential movement of the right and left side jacks.

(2) Pitching motion is produced by extension or retraction of the side jacks in unison while the rear jack remains stationary, or by differential operation of the rear and side jacks, the side jacks then acting in unison.

(3) Acceleration in the direction of the No.3 wind axis is produced by simultaneous extension or retractions of all three jacks.

20. Angle of bank (β) is applied differentially to the left and right servos; $+\beta$ is connected to the right jack servo amplifier 13DG/a via summing resistor 13D/T7/R9, and $-\beta$ is connected to the left jack servo amplifier 13DH/a via summing resistor 13D/T5/R9. Variation of β thus produces differential movement of the side jacks in simulation of bank.

21. The signal representing acceleration along the No.2 wind axis, $\frac{F2}{MT}$, is inverted by amplifier 13DF/b to produce $-\frac{F2}{MT}$. The positive term is fed to the left jack servo system via /T5/R10, and the negative term is fed to the right jack servo system via /T7/R10. Variation of $\frac{F2}{MT}$ therefore produces differential operation of the side jacks in simulation of sideslip.

22. The sine of the angle between the flight path and the horizontal ($-n_1$) is fed to both side jack servo systems, via /T7/R7 (right jack) and /T5/R7 (left jack) to provide simultaneous operation of the side jacks. The aircraft angle of incidence ($-\alpha$) is fed

to both side jack servo systems, via /T7/R6 (right jack) and /T5/R6 (left jack), to provide simultaneous operation of the side jacks. Variations of $-n_1$ and $-\alpha$ therefore produce pitching motion, negative functions being used to give the required direction of operation of the jacks.

23. The signal representing the compression of the landing gear oleo legs, $+d_m$, is fed to the three servo systems via /T7/R15a and b (right jack), /T5/R15a and b (left jack), and /T6/R3 (rear jack). When touchdown conditions are simulated, d_m will be a positive voltage, causing a retraction of all three jacks. Capacitors /T7/C15 and /T5/C15 smooth-out sudden changes in the d_m signal.

24. Vibration of the platform to simulate taxying effects is achieved by connection of the taxi rumble noise signal from the air noise unit (Part 5, Chap. 8A) to the two side jack servo systems. The taxi rumble signal is fed to the two servo systems via contact set 13A/T1/RL7/2 (operated at mainwheels touchdown), summing resistors /T7/R14 and /T7/R13 (right jack), /T5/R14 and /T5/R13 (left jack). Contact sets 13D/T9/RL4/1 and /RL4/2 (operated at nosewheel touchdown by a signal from the height and touchdown system, Part 8, Chap. 7, via interconnection (10)) release when the nosewheel leaves the ground; the proportion of taxi rumble signal summed with the other flight signals thus decreases to provide simulation of vibration due to mainwheels alone. When the mainwheels become airborne, 13A/T1/RL7/2 releases and the landing gear d_m signal is removed.

25. Fuselage motion associated with the application of engine power to taxy the aircraft from standstill (or when taking-off) is simulated by connecting -50V via contact set 13B/T1/RL4/3 (operated when $V_T \neq 0$) and via summing resistor 13D/T6/R22 to the input of the rear jack servo amplifier. The rear jack then extends by about one tenth of its maximum travel, to produce the appropriate nose-down attitude.

26. The effects of stall are reproduced by the connection, via interconnection (8), of a negative signal to the rear jack servo via /T6/R23. This input is derived from the $-n_1$ signal and is connected to the motion drive system via a relay contact set (in the drag loop) that operates at the point of stall.

27. The output of the buffet oscillator (para. 29), the amplitude of which is controlled by the buffet oscillator drive signal L_B-L (lift loop, Part 8, Chap. 3), is fed to the servo systems of the side jacks via /T7/R12 (right jack) and /T5/R12 (left jack). The buffet oscillator unit produces an output only when the drive signal is negative, i.e., from 0V to -7V; buffeting is, therefore, produced when gross lift L exceeds buffet lift L_B and consequently the platform oscillates in pitching motion at a frequency of approximately 5c/s. The buffet oscillator is constructed on a feedback board in position 13D/T8; the description of the buffet oscillator circuit is included in this chapter because it is a non-standard unit.

BUFFET OSCILLATOR

28. The buffet oscillator contains a low-frequency, square-wave oscillator, the output of which is integrated to produce a triangular waveform at the output of the unit. The amplitude of the output waveform is variable between 0 and 8V peak-to-peak and is controlled by a d.c. signal input. The frequency of the oscillator can be varied, by means of a preset control, over an 8 : 1 range; three frequency ranges can be obtained by connecting external links to select different values of timing and integrating capacitors.

Circuit description (C54059/01)

29. Transistors VT3 and VT4 (OC202) form an emitter-timed astable multivibrator in which the bases and collectors are cross-coupled via emitter followers VT14 and VT15 (OC202). A single timing capacitor, formed by various series/parallel connections of C1a and C1b, is connected externally between the emitters of VT3 and VT4. The use of only one timing capacitor eliminates starting problems that are associated with more conventional astable multivibrators, because it is impossible for both transistors VT3 and VT4 to be in the same state simultaneously.

30. Transistors VT1 and VT2 (OC202) form part of the emitter loads for VT3 and VT4. By varying the base bias, and therefore the collector currents, of VT1 and VT2, variation of the multivibrator frequency is obtained; this follows from the relationship:

$$T \approx \frac{C1Ve}{I_e}$$

where T = timing period (pulse width)
V_e = emitter voltage
I_e = current through emitter load.

The base bias voltage for VT1 and VT2 is obtained from the wiper of preset frequency control potentiometer RV1, adjustment of which gives a frequency variation of 8 : 1.

31. VT16, R29, R30, and C5 are included in the circuit to ensure self-starting regardless of the order in which the power supplies are switched on.

32. The output of the multivibrator is taken from VT15 emitter and is fed to an amplitude control circuit consisting of VT5 and VT6 (OC139), VT7 and VT8 (OC202), VT9 (OC139), and VT10 (ACY21). The negative excursion of the waveform at VT5 emitter is limited by VT6, the base voltage of which is controlled, via emitter followers VT7 and VT8, by the amplitude control input from PL1/16. The signal at VT6 emitter has a superimposed d.c. bias which follows the amplitude control voltage;

this bias would tend to adversely affect the operation of VT10 and is, therefore, cancelled-out by VT9, R16, R17, R18 and R19. Diodes MR3 and MR4 limit the maximum value of amplitude control input voltage to 0V and -6·8V.

33. The signal from VT10 collector is applied to the d.c. amplifier consisting of VT11 (OC202), VT12 (OC139) and VT13 (ACY21), and is integrated by virtue of C3, R21 and RV2. The value of C3 can be altered, to suit the particular frequency of the signal to be integrated, by external links to obtain various combinations of C3a and C3b. Resistor R25 and capacitor C6 introduce some phase-lag into the d.c. amplifier circuit to enhance the low-frequency response. The maximum output amplitude can be adjusted between 5V and 8V peak-to-peak by means of RV2 and the d.c. output level can be preset by means of RV3.

34. Internal regulated supplies of -6·8V, -13·6V, and +16·8V are obtained using Zener diodes MR8 and MR9 for the negative supplies, and MR5, MR6, and MR7 for the +16·8V supply.

Power supplies

35. The buffet oscillator unit requires the following power supplies:

(1) +27V unregulated - 30mA

(2) -27V unregulated - 35mA.

Voltage checks

36. The following typical circuit voltages are included as an aid to fault finding. The voltages given in Table 1 are measured, using a multimeter, with RV1 set to give the highest frequency within the range selected, the amplitude control input at 0V, and RV3 set to give 0V at the output, PL1/30. The setting of RV2 is unimportant for these measurements.

TABLE 1

Typical circuit voltages

Test point:	Electrode:	Voltage measured:
VT1, VT2 (OC202)	emitter	+7·6V
	base	+7·0V
	collector	+3·1V
VT3, VT4 (OC202)	emitter	+3·1V
	base	+4·4V
	collector	-2·5V
VT5, VT6 (OC139)	emitter	+1·2V
VT5	base	-2·0V
VT6	base	+1·3V
VT5, VT6	collector	+16·8V
VT7 (OC202)	emitter	+1·0V
	base	+0·5V
VT7, VT8 (OC202)	collector	-13·6V
VT8	emitter	+0·5V
	base	0V
VT9 (OC139)	emitter	+1·2V
	base	+1·3V
	collector	+6·3V
VT10 (ACY21)	emitter	+4·0V
	base	+3·7V
	collector	-13·6V
VT11 (OC202)	emitter	-6·5V
	base	-7·0V
	collector	-13·6V
VT12 (OC139)	emitter	-6·8V
	base	-6·5V
	collector	-0·1V
VT13 (ACY21)	emitter	0V
	base	-0·1V
	collector	-13·6V
VT14, VT15 (OC202)	emitter	-2·0V
	base	-2·5V
	collector	-13·6V
VT16 (ACY21)	emitter	+16·8V
	base	+16V
	collector	+7V
MR5 (KS36a)	cathode	+16·8V
MR6 (KS36a)	cathode	+11·2V
MR7 (KS36a)	cathode	+5·6V
MR9 (KS38a)	cathode	-6·8V
	anode	-13·6V

Performance details

37. The buffet oscillator performance is summarized as follows:

(1) Output waveform - triangular

(2) Output amplitude - 0 to 8V peak-to-peak

(3) Output impedance - < 10 ohms

(4) Maximum output load - 5 kilohms

(5) Amplitude control input impedance - 150 kilohms

(6) Output frequency - 1·5 - 40c/s (see Table 2).

Table 2 gives effective values of C1 and C3 for three frequency ranges.

TABLE 2

Frequency range connections

Frequency range:	C1:	C3:	Connect pins:
(1) (1·5 - 10c/s)	10μF	5μF	3 and 9 4 and 11 24 and 30 25 and 26
(2) (3 - 20c/s)	5μF	2·5μF	3 and 9 24 and 30
(3) (8 - 40c/s)	2·5μF	1·25μF	9 and 11 24 and 26

Normally, the unit is connected to give a frequency range of 1·5 to 10c/s, and RV1 is set to give an output at a frequency of 5c/s.

Test procedure

38. The following items of equipment are required for testing the buffet oscillator unit:

(1) Oscilloscope

(2) L.F. oscillator

(3) Multimeter

(4) 390-kilohm, 10 per cent, 1-watt resistor

(5) 56-kilohm, 10 per cent, 1-watt resistor

(6) 5·6-kilohm, 10 per cent, 1-watt resistor.

39. Connect power supplies as detailed in para.35. Connect the 390-kilohm and 56-kilohm resistors in series between PL1/16 and PL1/17, and the 5·6-kilohm resistor between PL1/30 and PL1/20. Connect the multimeter to PL1/30 and PL1/20 and adjust RV3 to obtain a zero-reading using the lowest d.c. voltage range (on the multimeter).

40. Connect links to PL1 to obtain frequency range (1) as given in Table 2. Connect the oscilloscope to PL1/30 and earth, and observe the triangular waveform output. Check that the peak-to-peak amplitude of the output can be varied from 5V to 8V by adjustment of RV2, with RV1 set at either end of its travel. Measure the frequency of the output on the oscilloscope by comparison with the output of the l.f oscillator. It must be possible to cover the range given in Table 2 by adjustment of RV1.

41. Connect links to PL1 to obtain frequency ranges (2) and (3), in turn, and repeat the tests detailed in para.40 for each of the ranges.

42. Remove the 390-kilohm and 56-kilohm resistors, and link PL1/16 to PL1/20; the output must then be zero.

PART 5

STANDARD UNITS

Chapter 1

INTRODUCTION

List of Contents

Standard units

1. The flight simulator systems utilize a number of standard units which, when necessary, can be easily replaced by spare units of an identical type; this interchangeability of units permits maximum utilization of the flight simulator for training purposes and minimizes delays when servicing the equipment.

2. Each standard unit is described in the individual chapters of this Part. Each chapter includes a general description, function of the unit, specification, performance details, circuit description, and test procedure. The test results are based on the use of test equipment which is listed in each chapter and specified in Part 13, Chap.3; if alternative test equipment to that specified is used, its accuracy must be equal to, or better than, that of the specified test equipment.

3. Where applicable, each chapter contains a list of the associated system circuit and test-circuit diagrams. The test-circuit diagrams are identified as Fig.1, 2, 3, etc. Each system diagram is identified by a capital letter C and the number 94598; this number (which identifies all systems on the Jetstar flight simulator) is followed by a suffix, e.g., /123. This suffix refers to system 123 on the Jetstar simulator. Circuit diagrams are identified by a capital letter followed by a five- or six-figure number and the suffix /01: this suffix identifies a circuit diagram as opposed to a

system diagram. Thus, diagram C94598/210 identifies the airspeed indicator system diagram in the Jetstar flight simulator; C99138/01 is the circuit diagram of the ±250V power supply circuit, and C208611/01 is the circuit diagram of the FB671 instrument drive amplifier.

Construction

4. The standard units are constructed in various forms according to the type and complexity of the unit. The larger units (power units, etc.) are contained on a standard-type chassis with the appropriate fuses, switches, etc., mounted on the front panel. Smaller-type standard units employ a printed-circuit form of construction; in some instances (i.e., d.c. computing amplifiers), the printed-circuit cards are attached to a narrow, vertical front panel. The smaller-type units are usually fitted into a crate which is rack mounted, or conveniently positioned within the rack structure

Plug coding system

5. A system of plug coding of edge-connectors of the computing amplifier units is employed to prevent insertion of a unit in the incorrect rack position. The coding consists of systematic positioning of special blank pins over specified pins on the edge connectors. Thus a standard amplifier unit may be readily interchanged but only with another unit of the identical type.

Heater supply levels

6. The heater supplies of the valve circuits of the standard units are connected to various d.c. levels to maintain the cathode/heater potentials within the recommended limits. These voltage levels are included in the "power supplies required" section of each chapter; it is important to note that, during bench tests of the standard units, the heater voltage levels are maintained by suitable connection of the heater transformer secondary outputs to the h.t. lines specified on the circuit diagrams.

Compute/zero switch

7. A compute/zero switch is mounted on the front panels of the d.c. amplifiers. The switch is not labelled and is normally set to the "compute" position (i.e., toggle deflected to the left); the "zero" position (i.e., toggle deflected to right), is used only during amplifier zero setting, when the amplifier circuits are balanced (zeroed) for minimum output with the amplifier inputs earthed via the switch.

Non-standard and auxiliary units

8. Most of the units of the flight simulator are of standard G.P.S. design and manufacture. However, the main fuse and indicator panel (in position 11A) is a non-standard unit and a description of this panel is not, therefore, given in this Part; the circuit and connections of the panel components are included in power supply distribution description (Part 3, Chap.3).

9. The auxiliary units consist mainly of power units not of G.P.S. manufacture; these units are described in separate publications supplied by the respective manufacturers. The auxiliary power units, voltage regulators and motor-alternator are listed in Part 3, Chap.2. An additional auxiliary unit is utilized in the audio system (Part 12, Chap.5); this unit comprises the Epsylon tape recorder, type MR700, which is used in conjunction with standard amplifiers, erase and bias oscillators, for tape-recordings of audio codes of the radio aids systems.

Summary of standard units

10. The individual chapters of this Part are arranged in groups under a common numerical designation as follows:

(1) Chapters 2A, 2B etc., describe d.c. computing amplifiers used mainly in the flight and engine computers. An integral drift corrector is incorporated in the amplifier unit type DEX (Chap.2B).
(2) Chapters 3A, 3B etc., describe the a.c. amplifiers used in the computing circuits of the chart and radio aids systems.
(3) Chapter 4 deals with the phase-sensitive rectifier unit type ZMA which contains two identical phase-sensitive rectifier sections.
(4) Chapters 5A, 5B etc., describe the standard power units of the flight computer and the radio aids power units which are independent in operation and are independently controlled.
(5) Chapters with the common numerical index 6 deal with the transistorized digital boards of the station selection digital system (Part 12, Chap.3); an introduction to the digital system is also included to present an overall view of the digital techniques employed, on the logical operation, and the testing procedure of the boards.
(6) Chapters with the common numerical index 7 describe the amplifiers and oscillators used in the audio system (Part 12, Chap.5) and in the marker system of the radio aids (Part 12). The erase and bias oscillators provide the necessary outputs for the tape recorder (para.9).
(7) Chapters with the common numerical index 8 include the units of the aircraft and engine noise systems which reproduce the noise effects, via loudspeakers, in the cockpit section of the simulator.

Chapter 2A

AMPLIFIER UNIT TYPE DE

List of Contents

List of Tables

List of Illustrations

General

1. Amplifier unit type DE contains a high-gain, high-power, d.c. computing amplifier capable of supplying a rated output of $\pm$100V into an external load of 1·5 kilohms. This amplifier is used in high-power applications such as providing drive for a velodyne motor-generator.

Circuit description (C54089/01)

2. The DE amplifier circuit consists of three long-tailed pairs, connected in cascade and followed by a cascode output stage.

3. The input stage, V1 and V2, comprises two low-noise a.f. pentodes (6059) connected as a long-tailed pair with a stage gain of approximately 100. The input to V1 is routed via zero/compute switch S1 which, in the "compute" position, selects the input signal, and in the "zero" position, connects V1 grid to earth via R46. The "zero" position is used for test of amplifier balance when minimum output should be obtained (para. 12) by the adjustment of potentiometer RV1, which is connected between the cathodes of V1 and V2, and with which the current through both valves is equalized, or unbalance in the succeeding stages is corrected. In this instance, the grid of V1 is connected to a potential divider of resistors R1 and R2, which are in the amplifier negative feedback loop, thus reducing the overall amplifier gain to approximately 18 to facilitate a more accurate balancing adjustment. A stabilizing network (C1 and R6) is included between the anodes of V1 and V2 to prevent h.f. oscillations.

4. The second stage, V3, consists of a high-mu double triode (12AX7) connected as a common-cathode differential amplifier with a gain of approximately 50. Neon indicator V8 lights when the stage becomes overloaded, and the voltage differential between the two anodes rises above the neon striking-voltage.

5. The third stage, V4, a high-mu double triode (12AT7), provides drive for the output stage and is fed from V3 anodes via the respective 5 : 1 divider networks (R9, 10, 11 and R12, 14, 15). Capacitor C17 shunts R14 to maintain the h.f. response. H.F. negative feedback from V4b anode, via C2, to V1 grid improves the amplifier stability. The gain of the driver stage is approximately 40.

6. The output stage, V5 and 6, consists of a pair of low-impedance pentodes (EL86) connected in cascode; the stage gain is approximately 2. The input valve (V6) is d.c. fed via a 5 : 2 divider network, R16, 20, 21, 37 and 38. Capacitor C15 shunts resistors R20 and 21 to restore the h.f. response. Network R39, C16 is included for h.f. stability reasons. R41 provides a partial d.c. feedback to improve the linearity of the output stage.

Power supply requirements

7. The following power supplies are required for the amplifier unit:

(1) 6·3V a.c. (earth level) - 1·36A
(2) 6·3V a.c. (-300V level) - 1·06A
(3) +300V d.c. (regulated) - 2mA

(4) -300V d.c. (regulated) - 2mA
(5) +300V d.c. (semi-regulated) - 24mA (zero V input)
(6) -300V d.c. (semi-regulated) - 24mA (zero V input)
(7) -500V d.c. (regulated) - 40μA (zero V input).

Performance details

8. Performance of the DE amplifier is as follows:

(1) Drift rate: 12 to 20mV in 8 hours
(2) Maximum output voltages when operating into an external load of 1·5 kilohms:

(a) -106V to +101V with a ±250V unregulated h.t. supply to the output stage
(b) -128V to +123V with a ±300V unregulated h.t. supply to the output stage
(c) -100V to +100V with a ±300V regulated h.t. supply to the output stage.

Voltage checks

9. Valve voltages listed in Table 1 provide a useful check when fault finding. The voltages are measured, by means of a multimeter, with respect to earth and with amplifier switch S1 set to the "zero" position.

TABLE 1

Valve voltages

Valve:	Pin No.:	Voltage measured:
V1, V2 (6059)	7 (anode)	+40V
	8 (screen grid)	+43V
	3 (cathode)	+1·5V
V3a and b (12AX7)	1, 6 (anodes)	+200V
	2, 7 (grids)	+40V
	3, 8 (cathodes)	+42V
V4a (12AT7)	1 (anode)	-80V
	2 (grid)	-194V
	3 (cathode)	-190V
V4b (12AT7)	6 (anode)	+55V
	7 (grid)	-194V
	8 (cathode)	-190V

TABLE 1 (Cont'd.)

Valve:	Pin No.:	Voltage measured:
V5 (EL86)	7 (anode)	+250V
	9 (screen grid)	+280V
	2 (grid)	-36V
	3 (cathode)	0V
V6 (EL86)	7 (anode)	-36V
	9 (screen grid)	-25V
	2 (grid)	-330V
	3 (cathode)	-300V

Test procedure

10. The following test procedure includes amplifier zero adjustment, and checks on the amplifier residual hum level, amplifier gain and overload indicator operation. The following test equipment is required:

(1) Oscilloscope
(2) D.C. valve voltmeter
(3) One 1·5-kilohm, 3-watt load resistor
(4) Two 1-megohm, ±1 per cent resistors
(5) One 150-kilohm, ±1 per cent resistor
(6) One 100-kilohm, ±1 per cent resistor
(7) One 47-kilohm, ±1 per cent resistor
(8) Two single-pole, change-over switches.

11. Connect the required power supplies to the DE amplifier unit under test and allow at least 2 to 3 minutes before switching on the h.t. supplies.

Zeroing and hum level tests

12. Connect the 1·5-kilohm load resistor between the amplifier output (PL1/A) and signal earth (PL1/P), and connect the valve voltmeter and oscilloscope in parallel with the resistor (Fig. 1). Set the DE amplifier zero/compute switch, S1, to the "zero" position, and adjust potentiometer RV1 to reduce the output, indicated by the valve voltmeter, to a minimum value. Check that the residual hum level, shown on the oscilloscope, is not greater than 25mV peak-to-peak (amplifier output zero).

Output voltage and neon indicator check

13. Connect the amplifier, as shown in the test circuit (Fig. 1), to give a gain of unity, i.e., connect a 1-megohm feedback resistor across the amplifier (PL1/A to PL1/AL) and a 1-megohm resistor in series with the input to PL1/AL. Set switch S1, in the test circuit, to the +300V position, and switch S2 to the 100V position. With the amplifier zero/compute switch (S1) set to the "compute" position, check that the amplifier output is approximately 100V and that the neon overload indicator (V8) is not lit. Repeat this check with the test-circuit switch, S1, set to the -300V position.

14. Set switch S2, in the test circuit, to the 150V position and check that the amplifier output is not less than 110V; the overload indicator should now be lit. Repeat this check with the test-circuit switch S1 in the +300V position.

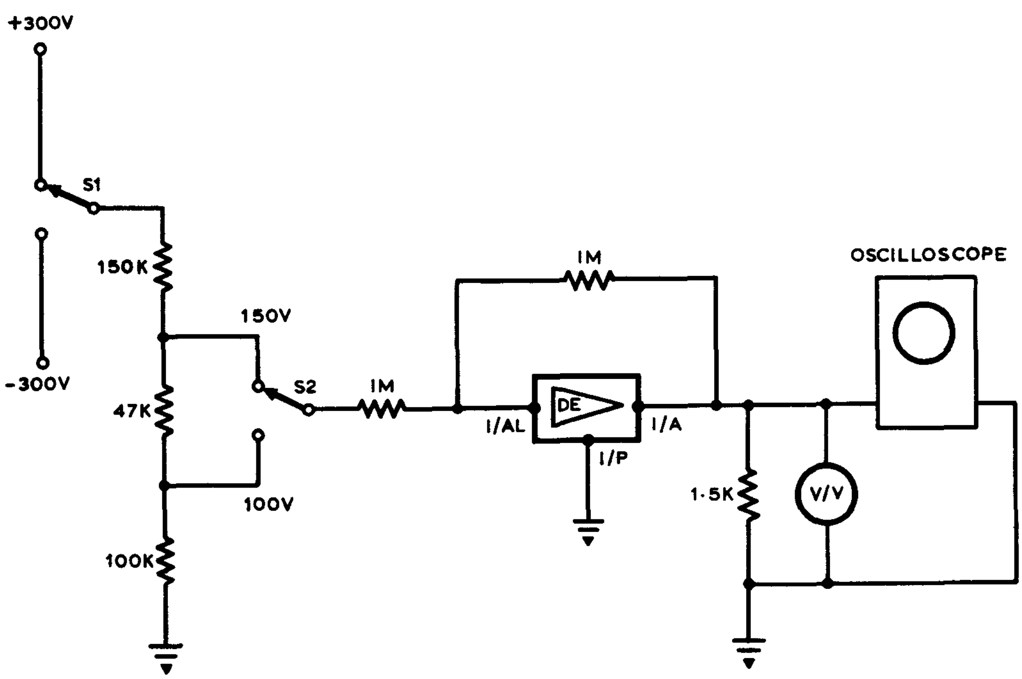


Fig.1 Amplifier unit type DE — test circuit

Chapter 2B

AMPLIFIER UNIT TYPE DEX

List of Contents

List of Tables

List of Illustrations

General

1. Amplifier unit type DEX contains a high-power, high-gain, d.c. amplifier, that is stabilized by an integral drift-corrector. The unit, which is used either in computer circuits or as a drive amplifier for d.c. servo motors, is capable of supplying an output of ±100V into a load of 1·5 kilohms.

Circuit description (C54090/01)

2. The amplifier circuit consists of three long-tailed pairs, connected in cascade followed by a cascode output stage. The drift corrector circuit comprises a two stage chopper-modulated amplifier and has a d.c. to d.c. gain of approximately 750.

Amplifier

3. The circuit and function of the DEX d.c. amplifier are similar to that of the type DE amplifier except that the DEX amplifier is drift-corrected by an integral drift corrector circuit.

4. The input stage, V1 and V2, comprises two low-noise a.f. pentodes (6059) connected as a long-tailed pair with a stage gain of approximately 100. The input to V1 is routed via zero/compute switch S1 which, in the "compute" position, selects the input signal, and, in the "zero" position, connects V1 grid to earth via R46. The "zero" position is used for tests of the amplifier balance when zero output should be obtained with both inputs of V1 earthed (para.17). Potentiometer RV1, which is connected between the cathodes of V1 and V2, is provided for adjustment of current through both valves, thus compensating also for any unbalance in the succeeding stages. A stabilizing network (C1 and R6) is included between the anodes of V1 and V2 to prevent h.f. oscillations. The grid of V1 is connected, via R8, to the output of the drift corrector (para.8).

5. The second stage, V3, consists of a high-mu double triode (12AX7) connected as a common-cathode differential amplifier with a stage gain of approximately 50. The neon indicator V8 is lit when the stage becomes overloaded and the voltage differential between the two anodes rises above the neon striking voltage.

6. The third stage, V4, is a high-mu double triode (12AT7), that provides the drive for the output stage, and is fed from V3 anodes via the respective 5:1 divider networks (R9, 10, 11 and R12, 14, 15). Capacitor C7 shunts R14 to maintain the h.f. response. H.F. negative feedback from V4b anode, via C2, to V1 grid, improves the amplifier stability. The gain of the stage is approximately 40.

7. The output stage, V5 and V6, consists of a pair of low-impedance pentodes (EL86) connected in cascode; the stage gain is approximately 2. The input valve of this stage (V6) is d.c.-fed via a 5:2 divider network comprising R16, 20, 21, 37 and 38. Capacitor C15 shunts resistors R20 and 21 to restore the h.f. response. R-C network, R39 and C16, ensures h.f. stability. R41 provides a partial d.c. feedback to improve the linearity of the output stage.

Drift corrector

8. The drift-corrector amplifier section, V7b and V7a, consists of a high-mu double triode (6057) connected in cascade with an overall gain of 3000 (at 50c/s). The input is fed, via a 50c/s hum filter (R24, 25 and C5), to the No.1 contact set of polarized relay RL1; the chopped d.c. signal is then applied to the two-stage amplifier V7; the amplifier output is demodulated by the No.2 contact of RL1/1 and is limited, by Zener diodes MR1 and MR2, to 500mV. The d.c. signal is smoothed by R36, C13 and is fed via R8 to the control grid of V2.

Power supply requirements

9. The following power supplies are required by the type DEX amplifier unit:

(1)	6·3V a.c.	(earth level)	-	1·72A
(2)	6·3V a.c.	(-300V level)	-	1·06A
(3)	+300V d.c.	(regulated)	-	2mA
(4)	-300V d.c.	(regulated)	-	2mA
(5)	+300V d.c.	(semi-regulated)	-	24mA (amplifier input zero V)
(6)	-300V d.c.	(semi-regulated)	-	25mA (amplifier input zero V)
(7)	-500V d.c.	(regulated)	-	40μA (amplifier input zero V).

Performance details

10. The performance of the DEX amplifier is similar to that of the DE amplifier with considerable improvement in the drift rate; the performance is as follows:

(1) Drift rate: 50μV to 100μV over a period of 100 hours

(2) Maximum output voltages when operating into an external load of 1·5 kilohms:

(a) -106V to +101V with a ∓250V unregulated h.t. supply to the output stage

(b) -128V to +123V with a ±300V unregulated h.t. supply to the output stage

(c) -100V to +100V with a ±300V regulated h.t. supply to the output stage.

Voltage checks

11. Typical valve voltages are listed in Table 1. The voltages are measured with respect to earth and with the amplifier compute/zero switch S1 in the "zero" position.

TABLE 1

Valve voltages

Valve:		Pin No.:	Voltages measured:
V1, V2	(6059)	7 (anode)	+40V
		8 (screen grid)	+43V
		3 (cathode)	+1·5V
V3	(12AX7)	1, 6 (anode)	+200V
		2, 7 (grid)	+40V
		3, 8 (cathode)	+42V
V4a	(12AT7)	1 (anode)	-80V
		2 (grid)	-194V
		3 (cathode)	-190V
V4b	(12AT7)	6 (anode)	+55V
		7 (grid)	-194V
		8 (cathode)	-190V
V5	(EL86)	7 (anode)	+250V
		9 (screen grid)	+280V
		2 (grid)	-36V
		3 (cathode)	0V
V6	(EL86)	7 (anode)	-36V
		9 (screen grid)	-25V
		2 (grid)	-330V
		3 (cathode)	-300V
V7	(6057)	1, 6 (anode)	+120V
		3, 8 (cathode)	+1V

Test procedure

12. The following test procedure includes amplifier zero adjustment, checks on amplifier residual hum level and gain, overload indicator operation, and gain check of the drift corrector amplifier.

D.C. amplifier tests

13. The following test equipment is required:

(1) Oscilloscope
(2) D.C. valve voltmeter
(3) One 1·5-kilohm, 3-watt load resistor

(4) Two 1-megohm, ±1 per cent resistors
(5) One 150-kilohm, ±1 per cent resistor
(6) One 100-kilohm, ±1 per cent resistor
(7) One 47-kilohm, ±1 per cent resistor
(8) Two single-pole, change-over switches.

14. Connect the 1·5-kilohm load resistor between the amplifier output, PL1/A, and signal earth PL1/P; connect the valve voltmeter and oscilloscope in parallel with the resistor (Fig.1).

15. Link PL1/AF to PL1/P thereby earthing the drift corrector output.

16. Connect the required power supplies to the DEX amplifier unit under test and allow 3 minutes to elapse before switching on the h.t. supplies.

17. Set the zero/compute switch S1 to the "zero" position, and adjust potentiometer RV1 to reduce the amplifier output, indicated on the valve voltmeter, to a minimum value. Check that the residual hum level, as displayed on the oscilloscope, is not greater than 25mV peak-to-peak (amplifier output zero).

18. Connect the amplifier, as shown in the test circuit (Fig.1), to give unity gain, i.e., connect a 1-megohm feedback resistor across the amplifier (PL1/A to PL1/AL) and a 1-megohm resistor in series with the input to PL1/AL. Set switch S1 (in the test circuit) to the +300V position and switch S2 to the 100V position. With the amplifier zero/compute switch S1 set to the "compute" position, check that the amplifier output is approximately 100V and that the neon overload indicator (V8) is not lit. Repeat this check with the test-circuit switch S1 set to the -300V position.

19. Set switch S2 (in the test circuit) to the 150V position and check that the amplifier output is not less than 110V; the overload indicator should light. Repeat this test with the test-circuit switch S1 in the +300V position.

20. Remove the link between PL1/AF and PL1/P, and disconnect the test circuit.

Drift corrector tests

21. The following test equipment is required:

(1) D.C. valve voltmeter calibrated against a laboratory-standard instrument prior to the tests
(2) Voltage divider box
(3) One 12V dry-cell battery for the voltage divider box supply
(4) One 1·5 dry-cell battery.

22. Set switch S1 (on the amplifier) to the "zero" position and ensure that the power supplies have been switched on for at least 10 minutes; then check that the valve voltages of V7 are as stated in Table 1.

23. Set switch S1 (on the amplifier) to the "compute" position and connect the output of the voltage divider box to PL1/AL; adjust the input signal to 1mV. With the valve voltmeter, measure the drift correction output between PL1/AF and PL1/P; the change in the output voltage, when the 1mV input is applied, must be between 500mV and 1200mV (use the compute/zero switch S1 to achieve the required condition). The ratio of the two voltages represents the d.c. gain of the drift corrector amplifier.

Note...
An appreciable time-delay is built into the output of the drift corrector amplifier.

24. Repeat the test procedure detailed in para.23 with the polarity of the input signal reversed.

25. Disconnect the divider box and set the compute/zero switch S1 to the "zero" position. With the valve voltmeter, measure the residual output between PL1/AF and PL1/P (see Note para.23). Divide this measured output by the gain measured in para.23. The result must not exceed 250μV.

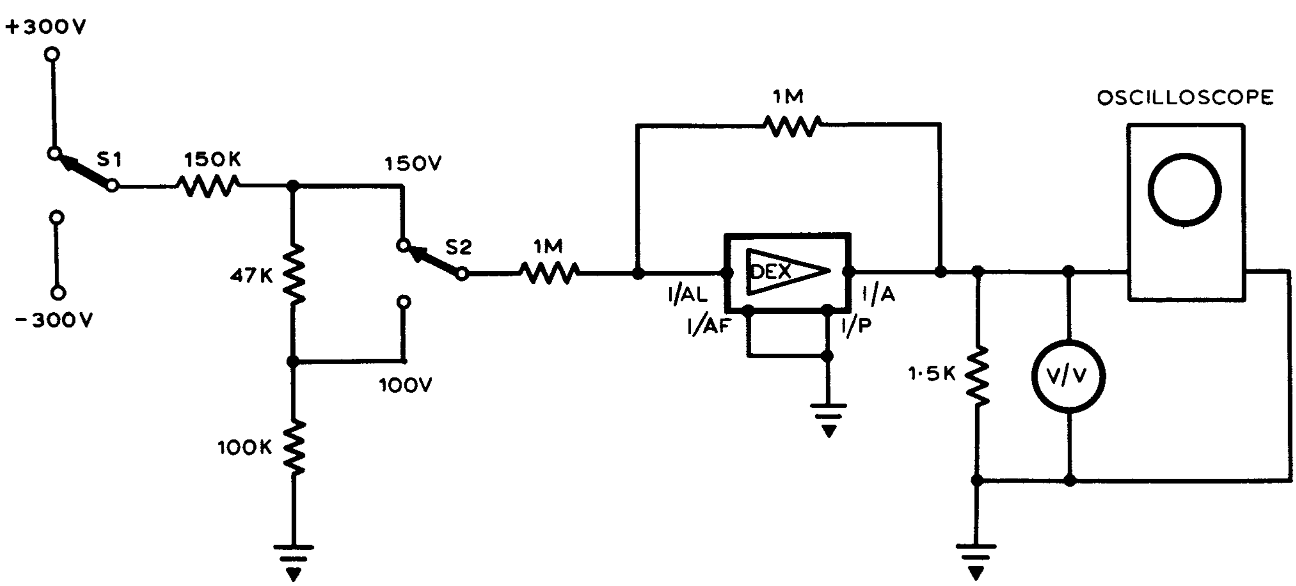


Fig. 1 Amplifier unit type DEX–test circuit

Chapter 2C

AMPLIFIER UNIT TYPE DH

List of Contents

List of Tables

List of Illustrations

General

1. Amplifier unit type DH contains two separate medium-gain low-power d.c. amplifier sections. This unit will supply an output of $\pm$100V into an external load of 15 kilohms.

Circuit description (C54091/01)

2. The two amplifier sections are identical except for component references and only section 1 is described. Section 1 amplifier consists of three long-tailed pairs, connected in cascade and followed by a cathode-follower output stage.

3. The input stage, V1, comprises a double triode (6060) connected as a long-tailed pair with a stage gain of 40 to 50. The input to V1a is routed via zero/compute switch S1 which, in the "compute" position, selects the input signal, and in the "zero" position connects the grid of V1a to earth, via R2. The "zero" position is used for test of amplifier balance when minimum output should be obtained (para. 12) by the adjustment of potentiometer RV1, which is connected between the cathodes of V1, and with which the current through both halves of V1 is equalized, or unbalance in the succeeding stages is corrected. In this instance, the grid of V1a is connected to a potential divider of resistors R1 and R2, which are in the amplifier negative feedback loop, thus reducing the overall amplifier gain to approximately 18 to facilitate a more accurate balancing adjustment.

4. The second stage, V2, consists of a high-mu, double triode (12AX7) connected as a common-cathode differential amplifier with a gain of approximately 70. Capacitor C2 provides h.f. feedback to prevent oscillation which may result at large signal inputs.

5. Anti-phase signals from the anodes of V2 are applied to the V3 long-tailed pair which provides drive for the output stage. The grids of V3a and b are fed via the respective 5:1 divider networks (R11, 13, 14 and R8 9, 10); capacitor C4 introduces an h.f. phase-advance to improve the h.f. response.

6. The cathode-follower output stage, V4 and V8, utilizes the "a" halves of a matched pair of double triodes (12BH7); the "b" halves are similarly used for the section 2 amplifier output. This configuration ensures minimum cathode-heater potentials. The grid of V4a is directly coupled to the anode of V3a, but the grid of V8a is d.c. supplied from a 3:1 divider network comprising R16, R39 and R40. Capacitor C14 shunts R39 to maintain the h.f. response. When operated without an external load, the output stage is protected by an internal load consisting of R21 and non-linear limiting element (voltage-dependent resistor) MR2. A d.c. negative feed-back path from the anode to grid of V8a, via resistor R45, is included to improve linearity and stability. Capacitor C1 provides h.f. negative feedback across the amplifier to maintain h.f. stability.

Power supplies

7. The following power supplies are required by the amplifier unit:

(1)	6·3V a.c. (earth level)	-	1·8A
(2)	6·3V a.c. (-300V level)	-	1·2A
(3)	+300V d.c. (regulated)	-	5·2mA
(4)	-300V d.c. (regulated)	-	3·4mA
(5)	+300V d.c. (semi-regulated)	-	22·5mA (zero V input)
(6)	-300V d.c. (semi-regulated)	-	22·5mA (zero V input).

Performance details

8. Performance of the DH amplifier is as follows:

(1) Drift rate: 2mV to 10mV in 24 hours
(2) Maximum output voltages when operating into an external load of 15 kilohms:

(a) -110V to +110V with a ±270V semi-regulated h.t. supply to the output stage
(b) -122V to +120V with a ±300V semi-regulated h.t. supply to the output stage.

Voltage checks

9. Valve voltages listed in Table 1 provide a useful check when fault finding. The voltages are measured, by means of a multimeter, with respect to earth and with the amplifier switch S1 set to the "zero" position.

TABLE 1

Valve voltages

Valve:	Pin No.:	Voltage measured:
V1, V5 (6060)	1, 6 (anodes)	+97V
	2, 7 (grids)	0V
	3, 8 (cathodes)	+1·8V
V2, V6 (12AX7)	1, 6 (anodes)	+205V
	2, 7 (grids)	+97V
	3, 8 (cathodes)	+100V

TABLE 1 (Cont'd.)

Valve:	Pin No.:	Voltage measured:
V3, V7 (12AX7)	1, 6 (anodes)	-4V
	2, 7 (grids)	-202V
	3, 8 (cathodes)	-201V
V4 (12BH7)	1, 6 (anodes)	+244V
	2, 7 (grids)	-9V
	3, 8 (cathodes)	0V
V8 (12BH7)	1, 6 (anodes)	0V
	2, 7 (grids)	-196V
	3, 8 (cathodes)	-187V

Test procedure

10. Tests of the amplifier unit include amplifier zero adjustment, and checks on hum level and output voltage of each section. The following test equipment is required:

(1) D.C. valve voltmeter
(2) Oscilloscope
(3) One 15-kilohm, ±1 per cent resistor
(4) One 12-kilohm, ±1 per cent resistor
(5) Two 1-megohm, ±1 per cent resistors.

11. Connect the required power supplies to the DH amplifier unit under test and allow at least 2 to 3 minutes before switching on the h.t. supplies.

Zeroing and hum level tests

12. Connect the 15-kilohm load resistor between output of section 1 (PL1/AA) and signal earth (PL1/P), and connect the valve voltmeter and oscilloscope in parallel with the resistor (Fig. 1). Set the amplifier zero/compute switch, S1, to the "zero" position and adjust potentiometer RV1 to reduce the output signal to a minimum value. Check that the residual hum level, shown on the oscilloscope, is not greater than 50mV peak-to-peak (amplifier output zero).

13. Repeat the zeroing and hum level tests for section 2; refer to drawing C54091/01 for the relevant plug connections.

Output voltage check

14. Connect section 1 as shown in the test circuit (Fig. 1), to give a gain of unity, i.e., connect a 1-megohm feedback resistor across the amplifier (PL1/AA to PL1/AL) and a 1-megohm resistor in series with the input to PL1/AL. Set switch S1, in the test circuit, to the +300V position and set the section 1 amplifier zero/compute switch S1 to the "compute" position. The +150V d.c. input signal saturates the driver stage and, provided that the amplifier gain is approximately unity, a minimum output voltage of -112V should be obtained.

15. Repeat the output voltage measurement using an output load of 12 kilohms, and finally check for no-load conditions. Table 2 gives the minimum voltages which are acceptable for the various load conditions.

TABLE 2

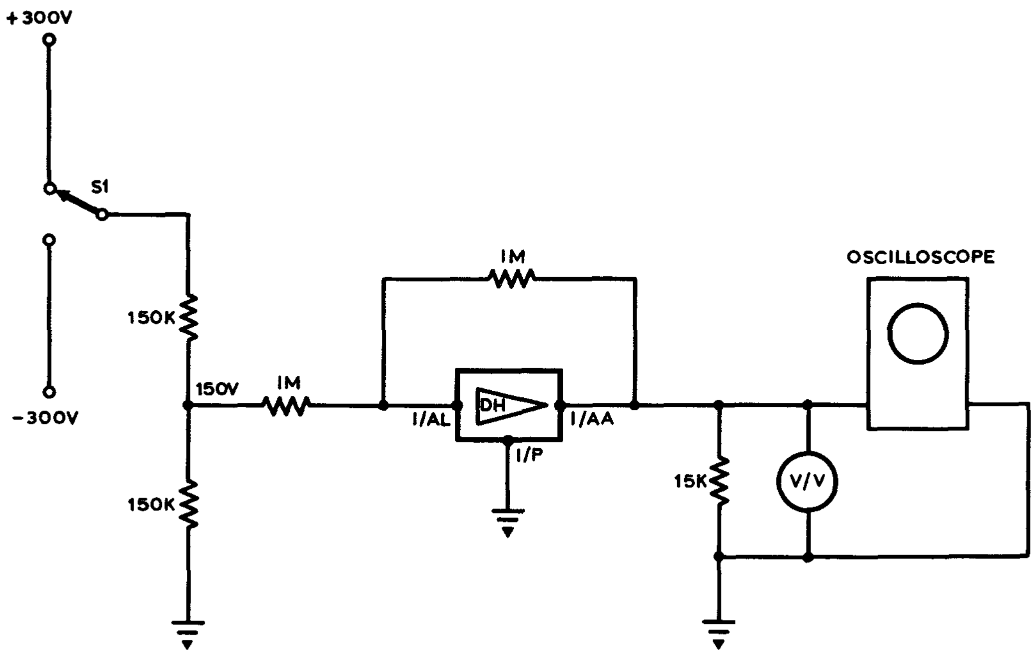
Output voltages

Output load:	Minimum output voltage:
Open-circuit	-135V
15 kilohms	-112V
12 kilohms	-103V

Note...
Output voltages exceeding 170V, at open-circuit load conditions, indicate a fault condition.

16. Reverse the polarity of the input signal and check that similar results, but of opposite polarity, to those in Table 2 are obtained.

17. Repeat the output voltage check (para. 14 to 16) for section 2 of the amplifier. Ascertain the plug references from the circuit diagram.



NOTES ...

1 Test circuit is shown for section 1 and 15K load.

2. Input for section 2 is PL1/A, output is PL1/V.

Fig. 1 Amplifier unit type DH — test circuit

Chapter 2D

ACTUATOR AND INSTRUMENT DRIVE AMPLIFIERS

List of Contents

List of Illustrations

General

1. The actuator drive amplifier and instrument drive amplifier units each contain direct-coupled current amplifiers that use similar transistorized single-ended push-pull circuits. The purpose of these units is to provide bi-directional drive currents for servo- and instrument-motors; the units thus function as power stages between computing amplifiers and motors. The two units differ in construction and in maximum available output voltage swing; separate descriptions of each unit are given in this chapter.

2. The actuator drive amplifier is used as a power output stage for computing amplifiers that control standard 24V d.c. actuator servo-motors. The unit is of compact construction which enables it to be fitted inside an actuator assembly.

3. The instrument drive amplifier consists of two identical sections (a) and (b), each of which employs a circuit similar to that of the actuator drive amplifier. Each section is used as a power output stage for computing amplifiers that control 10V d.c. instrument motors. The instrument drive amplifier unit is of feedback board construction.

ACTUATOR DRIVE AMPLIFIER

Circuit description (C99316/01)

4. The input d.c. signal is connected to the bases of transistors VT1 and VT2 via low-pass filter network R1 and C1: the filter prevents high-frequency components entering the amplifier. Diodes MR1 and MR2 limit the input voltage swing to ±27V, thus providing protection for VT1 and VT2.

5. With zero volts input at the input pin, transistors VT1, VT2, VT3 and VT4 are cut off. When a negative d.c. signal is applied to the input pin, VT2 and VT4 are cut off, and VT1 conducts; consequently, VT3 also conducts, and current flows from the -27V d.c. supply, via VT3 and the motor load, to earth. The motor shaft rotates at a speed proportional to the current supplied to the motor.

6. When a positive d.c. voltage is applied to the input, VT1 and VT3 are cut off, and VT2 conducts, producing a voltage drop across resistor R3. Transistor VT4 is thus forward-biased, and current flows from the load, via R4, VT4 and R5 to the +27V d.c. supply, i.e., in the opposite direction to the current flow when the polarity of the amplifier input is negative.

7. The current supplied to the load is, in direction and magnitude, directly proportional to the d.c. voltage applied to the amplifier input.

8. Diodes MR3 and MR4 limit the output voltage to ±27V, thus providing protection for transistor VT3 and VT4 against back-e.m.f. developed in inductive loads.

Power supplies

9. The actuator drive amplifier requires the following power supplies:

(1) +27V d.c. - 100mA
(2) -27V d.c. - 100mA.

Both supplies must be regulated to within 5 per cent and must not contain more than 1V peak-to-peak ripple.

Performance details

10. The amplifier is used as a power stage in servo-loops where 24V motors are controlled by standard computing or servo amplifiers. The performance is as follows:

(1) Maximum input voltage - ±120V
(2) Voltage gain - 0·6
(3) Current gain - 400
(4) Output voltage swing - ±24V d.c.
(5) Maximum output current - 100mA
(6) Frequency response - d.c. to 100c/s.

Voltage checks

11. Typical transistor voltages are not given for the actuator drive amplifier because these voltages depend on the amplitude of the input signal, and the unit does not contain d.c. supply stabilization.

Test procedure

12. The actuator drive amplifier does not require setting-up; tests are, therefore, confined to the overall functioning of the unit. The following items of test equipment are required:

(1) Variable ±27V d.c. supply
(2) 820-ohm, 3-watt, resistor
(3) Two multimeters.

In the following tests, all voltages are measured with respect to earth.

13. Connect the required power supplies, (para. 9) to the unit under test. Connect the 820-ohm resistor between the output pin of the unit and the common power returns (0V) of the power units.

WARNING...
THE AMPLIFIER OUTPUT MUST NOT BE SHORT-CIRCUITED TO EARTH. FAILURE TO COMPLY WITH THIS INSTRUCTION COULD RESULT IN FAILURE OF THE TRANSISTORS.

Connect a link from the signal earth return (C1 on the circuit diagram) to the common power earth return. Connect the output of the variable power supply between the amplifier signal input (R1 on the circuit diagram) and the signal earth return.

14. Switch on the power supplies and the variable test supply; connect one of the multimeters across the input terminals and connect the second multimeter across the output terminal. Vary the output voltage of the variable supply from +27V to -27V and measure the amplifier output voltage. The output voltage must be of the same polarity as the input voltage, and must be within 15 per cent of the input voltage for all settings of the variable supply between the limits of $\pm$27V. The amplifier output must be limited to $\pm$27V; any further increase of input voltage must not increase the output voltage.

INSTRUMENT DRIVE AMPLIFIER (FB671)

Circuit description (C208611/01)

15. The two sections of the instrument drive amplifier are identical except for component references and only section (a) is described.

16. The supply voltage to VT1 and VT3 is stabilized at -11·2V by R1 and Zener diodes MR1 and MR2. Similarly, the supply voltage to VT2 and VT4 is stabilized at +11·2V by R2, MR3 and MR4.

17. The input signal is connected to the bases of transistors VT1 and VT2 via the low-pass filter network, R3 and C1. The filter prevents high-frequency components entering the amplifier. Diodes MR5 and MR6 protect transistors VT1 and VT2 by limiting their base voltages to $\pm$11·2V.

18. With zero voltage input at PL1/10, all four transistors are cut off. When a negative d.c. signal is applied to PL1/10, VT2 and VT4 are cut off, and VT1 conducts and, in turn, causes VT3 to conduct. Consequently, current flows from the negative supply, via VT3 and the motor load, to earth; the motor shaft rotates at a speed proportional to the current supplied to the motor.

19. When a positive d.c. voltage is applied to the input, VT1 and VT3 are cut off, and VT2 conducts, producing a voltage drop across R5. VT4 is thus forward-biased, and current flows in from the external load, via R6, VT4 and R7, to the positive supply, i.e., in the opposite direction to the current flow through the load when the polarity of the input to the amplifier is negative.

20. The current supplied to the load is directly proportional, in direction and magnitude, to the d.c. signal applied to the input.

21. Diodes MR7 and MR8 limit the output voltage to ±11·2V, thus providing protection for VT3 and VT4 against back-e.m.f. developed in inductive loads.

Power supplies

22. Power supplies required by the instrument drive amplifier are:

(1) +27V d.c. - 60mA
(2) -27V d.c. - 60mA.

Both supplies must be regulated to within 5 per cent and must not contain more than 1V peak-to-peak ripple.

Performance details

23. The amplifier is used as a power stage in open loops where 10V instrument motors are controlled by computing amplifiers. The performance is as follows:

(1) Maximum input voltage - ±120V d.c.
(2) Voltage gain - 0·6
(3) Current gain - 400
(4) Output voltage swing - ±11·2V d.c.
(5) Maximum output current - 20mA
(6) Frequency response - d.c. to 100c/s.

Voltage checks

24. Typical transistor voltages are not given for the instrument drive amplifier because they depend on the amplitude of the input signal. Stabilized supply voltages must be as follows:

(1) Zener diode MR1 anode - -11·2V d.c.
(2) Zener diode MR4 cathode - +11·2V d.c.

These voltages are measured, with respect to earth, using a multimeter. The same conditions apply to Zener diodes MR11 and MR14, in section (b).

Test procedure

25. The instrument drive amplifier does not require setting-up; tests are, therefore, confined to the overall functioning of the unit. The following items of equipment are required:

(1) Variable ±27V d.c. power supply
(2) Two 680-ohm, 0·25-watt, resistors
(3) Two multimeters.

In the following tests, all voltages are measured with respect to earth.

26. Connect power supplies to the instrument drive amplifier unit as follows:

(1) +27V d.c. - PL1/3
(2) -27V d.c. - PL1/1
(3) 0V return (both supplies) - PL1/5.

Connect a 680-ohm resistor from PL1/13 to PL1/5 (section (a)), and a 680-ohm resistor from PL1/22 to PL1/5 (section (b)). Connect the output of the variable d.c. supply to PL1/10 and PL1/15; connect the 0V return of this supply to PL1/5.

WARNING...
THE AMPLIFIER OUTPUT MUST NOT BE SHORT-CIRCUITED TO EARTH. FAILURE TO COMPLY WITH THIS INSTRUCTION COULD RESULT IN FAILURE OF THE TRANSISTORS.

27. Switch on the normal power supplies and, using the multimeter, check that the Zener diode voltages, of both sections (a) and (b), are as given in para.24.

28. Switch on the variable d.c. supply, connect one of the multimeters to PL1/10, and connect the second multimeter to PL1/13. Vary the output voltage of the variable supply from +27V to -27V and measure the amplifier output voltage at PL1/13. The output voltage must be of the same polarity as the input voltage, and must be within 15 per cent of the input for settings of the variable supply between the limits of ±11·2V. The amplifier output must not exceed ±11·2V; any further increase of input voltage must not increase the output voltage.

29. Transfer the multimeter from PL1/13 to PL1/22 and repeat the tests, detailed in para.28, for section (b).

Chapter 3A

400C/S AMPLIFIER AND PHASE SENSITIVE RECTIFIER TYPE ZDA

List of Contents

List of Tables

List of Illustrations

General

1. The ZDA unit contains a 400c/s buffer amplifier section and a phase-sensitive rectifier (p.s.r.) section. The amplifier is capable of supplying a drive of 60V r.m.s either into the p.s.r. section, or into an inductive load of a synchro-resolver that is capacitively-tuned to 400c/s. The open loop gain of the amplifier is 65dB. The p.s.r

section provides a d.c. output approximately equal to the r.m.s. value of the a.c. input, and peak-to-peak ripple is approximately 5 per cent of the d.c. output level. The two sections are independent in operation but utilize common h.t. and heater supplies. For certain circuit applications the output of the amplifier can be connected externally to the input of the p.s.r. section.

Amplifier circuit (C37770/01)

2. The 400c/s amplifier section consists of a two-stage amplifier V1 (12AX7) connected in cascade, and an output stage consisting of V2 (12BH7) connected in cascode. The general circuit is similar to one section of the type ZHA amplifier unit (Chap.3B) except for component references.

3. The 400c/s input is applied to the grid of V1a via resistor R1; the anode of V1a is coupled to the grid of V1b via R7, C2 and C3. R7 and C2 have a time-constant of approximately 1·7 seconds to provide an adequate low-frequency response of the amplifier; C3 is of relatively low capacitance-value and ensures good h.f. response.

4. The output of V1b is connected, via C6 and R11, to the grid of V2b of the cascode-connected output stage. Additional frequency-compensation is achieved by C5 and R12 which are connected between the cathode of V1a and the grid of V2b. Biasing of the grids of V2a and V2b is arranged conventionally from potential-dividers in the cathode circuits, via resistor R13 for V2a and via R10 for V2b. The circuit of the output stage includes a d.c. negative feedback loop via resistor R14. The output signal is taken from the cathode of V2a via capacitor C8.

P.S.R. circuit (C37770/01)

5. The p.s.r. section consists of a diode bridge formed by V3 and V4 (6AL5), a phase-reference transformer T1 and a cascode-connected output stage, V5 (12BH7). The circuit is similar to one section of the p.s.r. unit type ZMA (Chap.4) except for component references.

6. A 400c/s reference voltage is fed from the secondary of transformer T1 to capacitor C2 in the centre arm of the bridge. Provided that no (400c/s) input signal is present, the capacitor charging current from T1 secondary is equally distributed through the diodes of the bridge; the bridge is thus balanced and, therefore, there is no voltage difference across resistors R20 and R22 which are connected between the input and the output of the bridge.

7. When a 400c/s input is applied to the bridge, via C10, the bridge becomes

unbalanced and more current flows through one arm than the other of the bridge. A rectified d.c. voltage-difference is developed across resistors R20 and R22; the polarity of the rectified voltage depends on the phase-relationship of the input voltage with respect to the reference voltage. The d.c. voltage consists of rectified half-cycles of 400c/s which are smoothed by capacitor C12 and applied via resistor R25 to the grid of the output stage V5b. Resistor R22 is also used as grid leak for the grid of V5b and is connected to the wiper of preset potentiometer RV1 which establishes the working bias potential of the output stage. The grid of output valve V5a receives a fixed bias, via R30, from the junction of R26 and R27 which, together with RV1, are connected in series across the -250V supply. The d.c. output is taken from the cathode of V5b.

Power supply requirements

8. The power supplies required to operate the unit are as follows:

(1)	6·3V a.c.(earth level)	2·1A
(2)	+250V d.c.	35mA
(3)	-250V d.c.	35mA
(4)	115V, 400c/s a.c.	1mA.

Voltage checks

9. The typical valve voltages listed in Table 1 are measured with respect to earth using a multimeter.

TABLE 1

Valve voltages

Valve:	Pin No.:	Voltage measured:
V1a, V1b (12AX7)	1, 6 (anode)	+180V
	3, 8 (cathode)	+0·9V
V2a (12BH7)	1 (anode)	+210V
	3 (cathode)	+10V
V2b (12BH7)	1 (anode)	+4V
	3 (cathode)	-244V
V5a (12BH7)	1 (anode)	0V
	3 (cathode)	-170V
V5b (12BH7)	1 (anode)	+225V
	3 (cathode)	0V

Test procedure

10 Tests of the amplifier section include gain and waveform tests; the tests of the p.s.r. section consist of operational checks on the a.c./d.c conversion efficiency of the circuit. The following test equipment is required:

(1) Multimeter
(2) Oscilloscope
(3) A.C. valve voltmeter
(4) Signal generator
(5) Transformer 115V, 400c/s, 1:1 ratio
(6) One 1-megohm, 0·5-watt, ±2 per cent resistor
(7) One 100-kilohm, 0 5-watt, ±2 per cent resistor
(8) One 47-kilohm, 0 5-watt, ±2 per cent resistor
(9) Three 10-kilohm, 1-watt, ±10 per cent resistors
(10) Two 47-kilohm, 1-watt, ±10 per cent resistors
(11) One 100-kilohm potentiometer

11. Connect the required power supplies to the unit under test and allow at least 2 to 3 minutes before switching on the h.t supplies

Amplifier gain test

12 Set the signal generator to give a 400c/s output of approximately 10mV Apply this signal to the input (SKT1/1) of the amplifier. Connect the 47-kilohm, 2 per cent, resistor between the amplifier output terminal, SKT1/3, and earth, SKT1/10 Connect the oscilloscope across this 47-kilohm resistor and check that an output is obtained. Replace the oscilloscope with the valve voltmeter and increase the input signal level; the maximum output signal from the amplifier must be greater than 60V r.m.s.

Amplifier waveform test

13. Connect the 1-megohm feedback resistor between the amplifier input and output terminals, SKT1/1 and SKT1/3 Connect the 100-kilohm resistor in series with the signal generator supply to the input terminal, SKT1/1. With the oscilloscope connected across the amplifier output, check that the output waveform is free from instability at various levels of input signal, i.e., between zero volts and an input level which overloads the amplifier

14. Connect the 100-kilohm resistor in the feedback loop, between SKT1/1 and SKT1/3, and the 1-megohm resistor in series with the signal generator output and SKT1/1. With the oscilloscope, check that the amplifier output waveform is free

from instability at all levels of the input signal.

15. Disconnect the test equipment and switch off the power supplies.

P.S.R. section test

16. Connect the p.s.r. section test circuit as shown in Fig. 1. Switch on the power supplies and allow a warm-up time of approximately 5 minutes to elapse. Set the wiper of the 100-kilohm potentiometer for zero volt output (measured on the valve voltmeter) with respect to signal earth. With the multimeter connected between SKT1/11 and earth, adjust RV1 (on the unit) to obtain zero volt reading on the multimeter.

17. Increase the voltage at the wiper of the 100-kilohm potentiometer to 20V r.m.s., as measured on the a.c. valve voltmeter, and check that the d.c. voltage measured on the multimeter is approximately 20V.

Note...
If the input voltage is in phase with the reference voltage, the output should be positive and vice versa. Alter the test-circuit transformer primary connections, as necessary, to achieve this condition.

18. Reverse the phasing of the input voltage by adjusting the position of the wiper on the 100-kilohm potentiometer until the a.c. valve voltmeter reads 20V r.m.s., and check that the d.c output voltage measured on the multimeter is approximately 20V and of opposite polarity to that measured in para. 17.

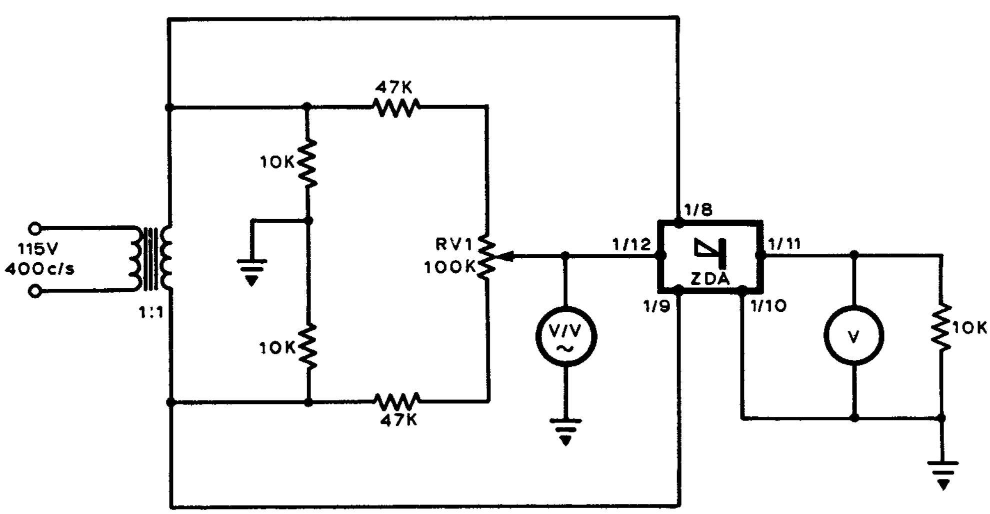


Fig.1 P.S.R section of ZDA unit-test circuit

Chapter 3B

AMPLIFIER UNIT TYPE ZHA

List of Contents

List of Tables

List of Illustrations

General

1. The type ZHA amplifier unit contains two separate a.c. buffer amplifier sections which are independent in operation, but which utilize common h.t. and heater supplies. The amplifiers are designed to operate at 400c/s and are capable of supplying a drive of 60V r.m.s. either into a resistive load of p.s.r. unit type ZMA, or into an inductive load of a tuned synchro resolver. The open loop gain of each amplifier section is 65dB

Circuit description (C37681/01)

2. The two amplifier sections are identical except for component references and only section 1 is described. Section 1 consists of a two-stage amplifier, V1a and V1b (12AX7) connected in cascade and followed by an output stage comprising V2a and V2b (12BH7) connected in cascode.

3. The 400c/s input signal is applied to the grid of V1a via resistor R1; the anode of V1a is coupled to the grid of V1b via R4, C3 and C2. The time-constant of R4 and C3 (approximately 1·7 seconds) provides adequate low-frequency response of the amplifier; the capacitance of C2 is of relatively low value and ensures good h.f. response. Cathode resistors R2 and R7 provide current feedback in their respective amplifier stages.

4. The output of V1b is connected via C7 and R14 to the grid of V2b of the cascode-connected output stage. Additional frequency compensation is achieved by C4 and R8 which are connected between the cathode of V1a and the grid of V2b. Biasing of the grids of V2a and V2b is arranged conventionally from potential-dividers in the cathode circuits, via resistor R13 for V2a and via resistor R12 for V2b. The circuit of the output stage includes a d.c. negative feedback loop via resistor R11. The output signal is taken from the cathode of V2a via capacitor C8.

Power supplies

5. The power supply requirements are as follows:

(1)	6·3V a.c. (earth level)	-	1·8A
(2)	+250V d.c.	-	40mA
(3)	-250V d.c.	-	40mA.

Voltage checks

6. The anode and cathode voltages of the amplifier valves are listed in Table 1 and provide a useful check when fault finding. The voltages are measured with respect to earth by means of a multimeter.

TABLE 1

Valve voltages

Valve:	Pin No.:	Voltage measured:
V1a, V1b, V21a, V21b (12AX7)	1, 6 (anodes)	+180V
	3, 8 (cathodes)	+0·9V
V2a, V22a (12BH7)	1 (anode)	+210V
	3 (cathode)	+10V
V2b, V22b (12BH7)	6 (anode)	+4V
	8 (cathode)	-244V

Test procedure

7. Tests of ZHA amplifier unit include gain and waveform tests. The following equipment is required for the tests:

(1) Oscilloscope
(2) A.C. valve voltmeter
(3) Signal generator
(4) One 1-megohm, 0·5-watt, ±2 per cent resistor
(5) One 100-kilohm, 0·5-watt, ±2 per cent resistor
(6) One 47-kilohm, 0·5-watt, ±10 per cent resistor.

8. Connect the required power supplies to the unit under test and allow at least 2 to 3 minutes before switching on the h.t. supplies.

Gain test

9. Set the signal generator to give a 400c/s output of about 10mV. Apply this signal to the input of the section 1 amplifier, SKT1/1. Connect the 47-kilohm resistor between the amplifier output terminal SKT1/2 and earth SKT1/10. Connect the oscilloscope across the 47-kilohm resistor and check that an output is obtained. Replace the oscilloscope with the valve voltmeter and increase the amplifier input signal level; the maximum amplifier output signal obtainable should be greater than 60V r.m.s.

10. Repeat the gain test procedure (para.9) for section 2 of the unit.

Waveform test

11. Connect the 1-megohm feedback resistor between the amplifier input and output terminals, SKT1/1 and SKT1/2. Connect the 100-kilohm resistor in series with the signal generator supply to the input terminal SKT1/1. With the oscilloscope connected across the amplifier output, check that the output waveform is free from instability at various levels of input signal, i.e., between zero volts and an input level which overloads the amplifier.

12. Connect the 100-kilohm resistor in the feedback loop, between SKT1/1 and SKT1/2, and the 1-megohm resistor in series with the signal generator output and SKT1/1. With the oscilloscope, check that the amplifier output waveform is free from instability at all levels of input signal.

13. Repeat the procedures in para. 11 and 12 for section 2 of the amplifier unit.

Chapter 3C

AMPLIFIER UNIT TYPE ZHB

List of Contents

List of Tables

List of Illustrations

General

1. Amplifier unit type ZHB contains a 400c/s amplifier with an integral automatic gain control section. The amplifier, which has an overall maximum gain of 82dB, delivers an output of 5 watts into an external load of 2·5 kilohms. The amplifier is

used in a.c. high-power applications such as the drive for a two-phase 400c/s servo motor. The amplifier output is 180 degrees out of phase with the input signal.

Circuit description (C37682/01)

2. The circuit consists of an automatic-gain stage, two amplifier stages and a cathode-follower output stage.

3. The input stage, V2, comprises a variable-mu pentode (EF92) the grid bias of which, and thus the stage gain, is controlled by a rectified external 400c/s signal. This gain-control signal is rectified by triode V1a (12AX7), which is connected as a diode, and the resulting d.c. bias is fed via R5 and R6 to V2 grid. Depending on the amplitude of the control signal (up to 56V r.m.s.) the gain of the input stage can be varied between +32dB and -12dB. The amplifier input signal is applied to V2 grid via resistor R2 and potentiometer RV1 by which the overall gain of the amplifier is preset to a required level, i.e., between zero and 82dB.

4. The second stage consists of triode amplifier V1b which is the second half of the double triode 12AX7; gain of this stage is approximately 26dB.

5. The output stage, V3 and V4, employs two pentodes (EL86) connected in cascode with a stage gain of 24dB. The anode signal of V1b is applied to V4 grid via C5 and R14. Amplifier output from V3 cathode is fed to the motor via capacitor C9. The parallel connected capacitors C10, 11, 18 and 19 tune the resonant frequency of the motor winding to 400c/s; the value of C18 is selected on test.

Applications

Synchro-resolver

6. When the ZHB amplifier is used to drive a synchro-resolver, the amplifier gain is preset to 60dB, by means of potentiometer RV1, with the gain-control signal at zero volts. One of the resolver-rotor coils is connected to the amplifier input, the other rotor coil being connected to the gain control input. One coil of the motor, which drives the resolver rotor, is connected to the amplifier output; the second coil is energized by an external reference voltage which is 90 degrees out of phase with the amplifier output voltage. The resolver stator coils are fed with two signals from the flight simulator; when resolved these signals establish the required stator position

7. When the flight simulator signals are applied to the stator coils, the synchro-resolver runs until the amplifier input signal is reduced to zero volts and the gain-control signal reaches a maximum level. Simultaneously the amplifier output

becomes zero volts and the motor stops. The rotor assumes a position and direction which represents the resultant of the signals from the flight simulator.

Motor-tacho-generator

8. When the amplifier is employed as an integrator driving a motor-tacho-generator, the gain control signal is not required, and potentiometer RV1 is set to its maximum input position. Velocity feedback from the tacho-generator is applied to the amplifier input. Overloading of the amplifier, with subsequent non-linear integration, due to the generator phase-difference, is prevented by connecting a capacitor in parallel with the overall feedback resistor; the capacitor value is determined by trial. The second coil of the two-phase motor is supplied with an external reference voltage which is in phase with the amplifier output.

Power supplies

9. The following power supplies are required by the ZHB amplifier unit:

(1)	6·3V a.c. (earth level)	-	1·26A
(2)	6·3V a.c. (-250V level)	-	0·76A
(3)	+250V d.c.	-	50mA
(4)	-250V d.c.	-	50mA.

Performance details

10. Performance of the ZHB amplifier is as follows:

(1) Output of 5 watts into a 2·5-kilohm load.
(2) Gain zero to 82dB (varied by means of RV1).
(3) Overall gain can be reduced by 44dB when a 50V r.m.s. control signal is applied to the input of the automatic gain circuit (maximum control voltage is 56V r.m.s.).
(4) With the appropriate correction for generator phase shift, linearity within 0·5 per cent of maximum motor speed can be achieved for amplifier gains up to 74dB; smooth motor response can be maintained for speeds below 10 rev/min.

Voltage checks

11. Valve voltages listed in Table 1 provide a useful check when fault finding. The voltages are measured, by means of a multimeter, with respect to earth and with the amplifier gain potentiometer (RV1) set to give a maximum input.

TABLE 1

Valve voltages

Valve:	Pin No.:	Voltage measured:
V1b (12AX7)	6 (anode)	+100V
	8 (cathode)	+1·0V
V2 (EF92)	5 (anode)	+95V
	7 (screen grid)	+110V
	2 (cathode)	+1·5V
V3 (EL86)	7 (anode)	+245V
	9 (screen grid)	+210V
	3 (cathode)	+35V
V4 (EL86)	7 (anode)	+15V
	9 (screen grid)	+15V
	3 (cathode)	-200V

Test procedure

12. Tests of the amplifier unit include checks on the overall gain, operation of the automatic gain control stage and check of the rectifier valve output. Equipment required for these tests is as follows:

(1) Two multimeters
(2) Oscilloscope
(3) A.F. attenuator
(4) 115V, 400c/s, 1:1 ratio transformer
(5) Two Variacs

and either:

(6) (a) 400c/s two-phase servo motor (G.P.S. part No. 36024)
(b) One 0·05-μF, 500V d.c. capacitor
(c) One 0·2-μF, 500V d.c. capacitor
(d) Two 0·02-μF, 500V d.c. capacitors

or:

(7) One 2·5-kilohm, 6-watt, wire-wound resistor.

13. Connect the amplifier and the test circuit as shown in Fig. 1.

Note...

If a servo motor is not available, replace the tuning capacitors C9, C10, C11, etc. by the 2·5-kilohm resistor connected between V3 cathode and earth, SKT1/10. In this instance, the amplifier output is measured across the resistor; the phase-shift capacitors (sub-para.12, (6b) to (6d)) are not, therefore, required.

14. Connect the power supplies to the unit; the valves should be allowed to warm up for at least 2 to 3 minutes before connecting the h.t. supplies.

15. Set potentiometer RV1 to the maximum gain position (fully clockwise). Connect one multimeter, set to 100V a.c. range, between the amplifier output, SKT1/11, and earth, SKT1/10; connect the other multimeter, set to 100V a.c. range, between the gain-control-voltage input, SKT1/3, and earth, and finally connect the oscilloscope, set to the 30mV range, between the amplifier input, SKT1/1, and earth. Set Variac 1 to give an input of 20V r.m.s. to the a.f. attenuator.

Overall gain check

16. Set Variac 2 to give zero control-voltage and set the attenuator so that the amplifier output is 40V r.m.s. The amplifier input voltage must not exceed 5mV r.m.s., i.e., the overall gain is approximately 8000.

17. Set the attenuator so that the amplifier output is 90V r.m.s. and check that the amplifier input is not greater than 12mV r.m.s.; the overall gain is approximately 7500.

Variable gain check

18. Set Variac 2 to give a control voltage of 2V r.m.s. and adjust the attenuator so that the amplifier output is 40V r.m.s. The amplifier input, say "X" mV r.m.s., should be noted.

19. Set the control voltage to 9V r.m.s. and the amplifier output to 40V r.m.s. The amplifier input must exceed 2·8 "X" mV r.m.s. (para.18).

20. Set the control volts to 50V r.m.s. and the amplifier output to 40V r.m.s. The amplifier input voltage must exceed 200 "X" mV r.m.s. (para.18).

Rectifier check

21. Disconnect the multimeter measuring the amplifier output and connect it between V1a anode (or SKT1/2) and earth (positive terminal); set the multimeter to the 100V d.c. range. Set Variac 2 to give a control voltage of 50V r.m.s. and check that the rectifier output is -30V to -35V d.c.

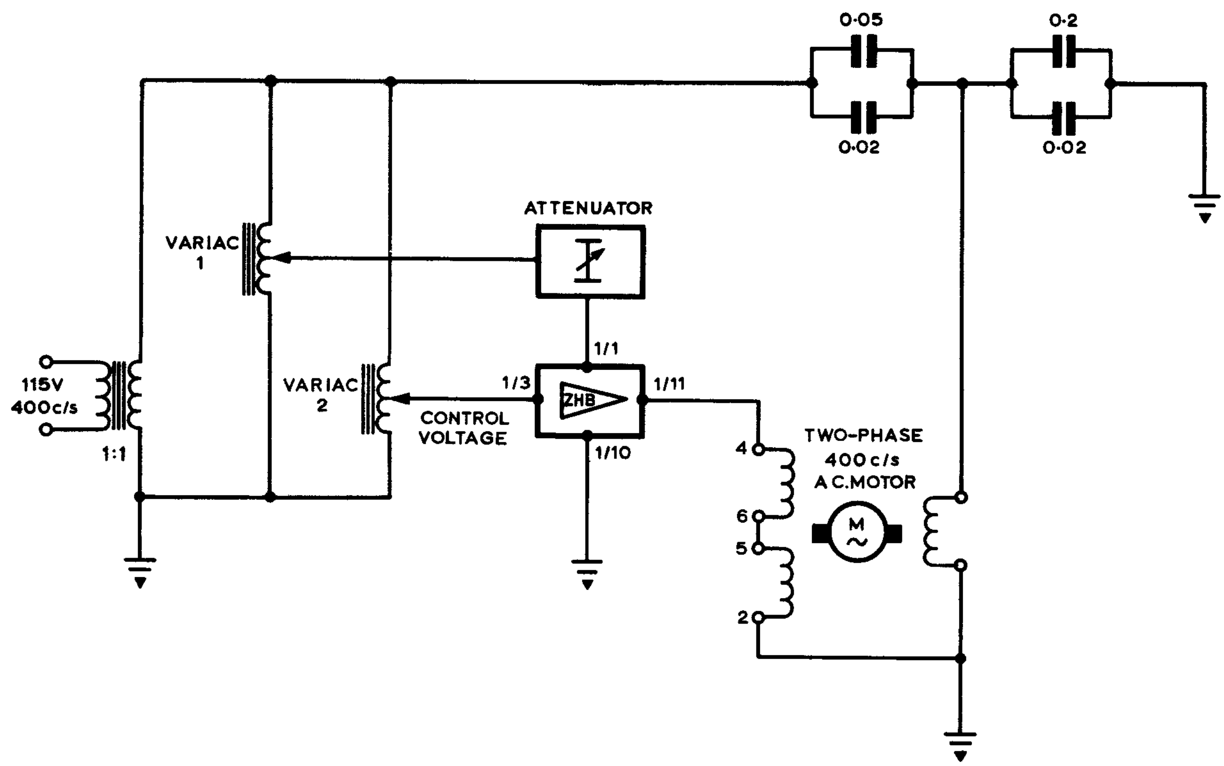


Fig. 1 Amplifier unit type ZHB – test circuit

Chapter 4

PHASE SENSITIVE RECTIFIER UNIT TYPE ZMA

List of Contents

List of Tables

List of Illustrations

General

1. The type ZMA phase sensitive rectifier unit (p.s.r.) contains two identical p.s.r sections, each consisting of a diode bridge, an output stage and a common phase-reference transformer. The d.c. output is approximately equal to the r.m.s. value of the input, and peak-to-peak output ripple is approximately 5 per cent of the d.c. output level.

Circuit description (C37683/01)

2. Section 1 is described; the other section is similar except for socket pin references, and valve and component references which, in section 2, are increased by 20.

3. The p.s.r. circuit consists of two pairs of diodes, V1 and V2 (6AL5), connected in a bridge circuit between the input and the output stage V3 (12BH7) which is arranged in a cascode cathode-follower configuration. The 400c/s reference voltage is fed from the secondary of transformer T1 to capacitor C2 in the centre arm of the bridge. Provided that no input signal is present, the capacitor charging current from T1 secondary is equally distributed through the diodes of the bridge; the bridge is balanced and, therefore, there is no voltage difference across resistors R2 and R3 which are connected between the input and output of the bridge.

4. When a 400c/s input is applied to the bridge, the bridge becomes unbalanced and more current flows through one arm of the bridge. A rectified d.c. voltage difference is developed across resistors R2 and R3; the polarity of the rectified voltage depends on the phasing relationship of the input voltage with respect to the reference voltage. The d.c. voltage consists of rectified half-cycles of 400c/s voltage which is smoothed by capacitor C3 and applied to the grid of the output stage V3a via resistor R6. Resistor R3 is also used as grid leak for the grid of V3a and is connected to the wiper of preset potentiometer RV1, which establishes the working bias potential of the output stage. The grid of the output valve V3b receives a fixed bias via R7 from the junction of R10 and R11 which, together with RV1, are connected in series across the -250V supply. The d.c. output is taken from the cathode of V3a.

Power supplies

5. The following power supplies are required for the ZMA unit:

(1)	6·3V a.c. (earth level)	-	2·4A
(2)	+250V d.c.	-	30mA
(3)	-250V d.c.	-	30mA
(4)	115V a.c., 400c/s	-	1mA.

Voltage checks

6. Valve voltages listed in Table 1 provide a useful check when fault finding. The voltages are measured with respect to earth by means of a multimeter.

TABLE 1

Valve voltages

Valve:	Pin No.:	Voltage measured:
V3a, V23a (12BH7)	6 (anode)	+225V
	8 (cathode)	0V
V3b, V23b (6AL5)	1 (anode)	0V
	3 (cathode)	-170V

Test procedure

7. Tests of the ZMA unit consist of operational checks on the a.c./d.c. conversion efficienty of the circuit. The following test equipment is required:

(1) Multimeter
(2) A.C. valve voltmeter
(3) Oscilloscope
(4) Transformer 115V, 400c/s, 1:1 ratio
(5) Three 10-kilohm, 1-watt, ±10 per cent resistors
(6) Two 47-kilohm, 1-watt, ±10 per cent resistors
(7) One 100-kilohm potentiometer.

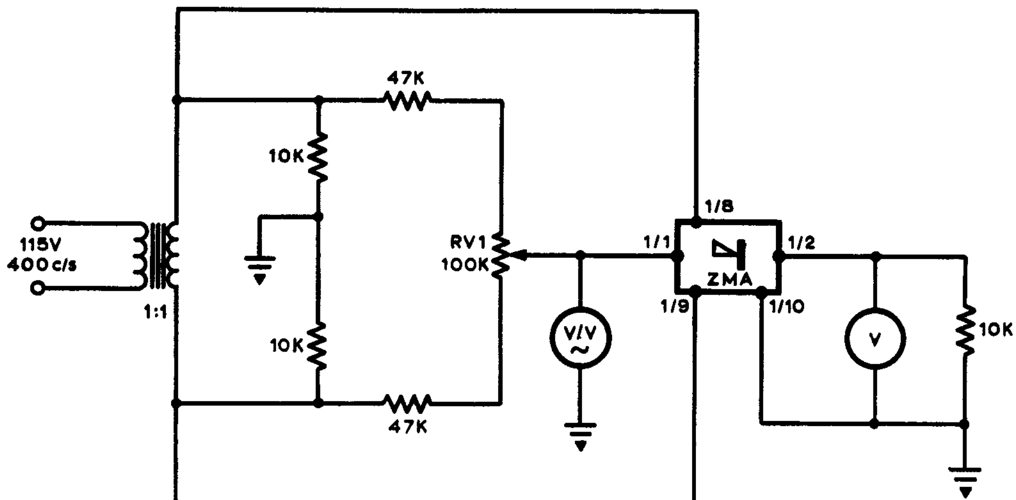
8. Connect the required power supplies to the unit and connect the test circuit as shown in Fig. 1. Set the wiper of the 100-kilohm potentiometer for zero volt output (measured on the valve voltmeter) with respect to signal earth. Connect the multimeter between SKT1/2 and signal earth, and adjust RV1 (in the unit) to obtain zero volt output.

9. Increase the voltage on the wiper of the 100-kilohm potentiometer to 20V r.m.s., as measured on the a.c. valve voltmeter, and check that the d.c. voltage measured on the multimeter is approximately 20V.

Note...
If the input voltage is in phase with the reference voltage at PL1/8, the output should be positive and vice versa. Alter the test-circuit transformer primary connections, as necessary, to achieve this condition.

10. Reverse the phasing of the input voltage by adjusting the position of the wiper on the 100-kilohm potentiometer until the a.c. valve voltmeter reads 20V r.m.s., and check that the d.c. output voltage measured on the multimeter is approximately 20V and of opposite polarity to that measured in para. 9.

11. Repeat the test procedure (para.8 to 10) for section 2 of the p.s.r. unit; refer to the circuit for component and socket references.



NOTES...

1. Test circuit is shown for section 1.
2. Input for section 2 is SKT1/12, output is SKT1/11.

Fig.1 P.S.R. unit type ZMA - test circuit

Chapter 5A

VOLTAGE REGULATOR TYPE 22G

List of Contents

List of Tables

List of Illustrations

General

1. The type 22G voltage regulator unit contains three regulated d.c. power supplies which deliver, respectively, +300V at 1A, -300V at 1A, and -500V at 8mA from a single-phase a.c. mains input of 200V to 250V, 45 to 65c/s.

2. The regulator unit contains the h.t. supplies transformer, heater transformer, bridge rectifiers, series valves of the +300V and -300V supplies, and three plug-in sub-chassis, each fitted with the respective control amplifiers for the three supplies; sub-chassis type 23 incorporates also the rectifier and the series valve for the -500V supply.

3. Regulation of the supplies is achieved by standard regulator circuits employing ripple amplifiers which control the grid potential of the series valves in the output lines. The -300V control amplifier type 2 utilizes a reference voltage obtained from a neon stabilizer valve, whereas the +300V control amplifier type 1 obtains its reference from the -300V supply line. The -500V regulator type 23 actually supplies an output of -200V which is added to the -300V regulated output.

Main chassis circuit (B208515/01)

4. The supply to heater transformer TR2 is routed directly from the instant a.c. supply of the distribution system on rack 11 via contact set 11X/CR1, fuse 11A/F18 (/500) and PL2/13; the h.t. transformer TR1 mains supply is routed from the delayed a.c. supply on rack 11, via contact set 11X/CR2, fuse 11A/F14 (/500), PL2/15 and the internal MAINS switch S1. This circuit arrangement ensures that the h.t. supplies are switched-on automatically after the valves have been heated.

5. The secondary windings of TR1 supply independent rectifier circuits and the series valves of the three regulated supplies. Both ±300V supplies utilize eight parallel-connected series valves (6080) which are controlled by separate amplifier units; the unregulated +460V supplies from rectifier bridges MR1 and MR2 are protected by independent fuses. The ripple content of the unregulated +400V supplies is approximately 13·5V peak-to-peak.

6. The supply to the -500V voltage regulator is approximately 300V a.c. The regulator unit contains a valve rectifier and a control circuit of the -200V output.

7. Control voltages for the two control amplifiers and the -500V regulator are obtained from external circuits so that the d.c. outputs of the unit are regulated by voltage variations at the external loads. The rack wiring does not, therefore, add to the output resistance of the regulated supplies. Capacitors C3 and C4 provide smoothing of the 300V regulated supplies. The main chassis also contains internal

load resistors (R65 and R66) for the 300V supplies. The smoothing capacitor for the -500V supply is contained in the voltage regulator unit type 23.

8. Heater transformer TR2 supplies three outputs of 6·3V which are connected to the +300V, 0V and -300V lines to provide heater supplies at these levels.

Control amplifier type 1 circuit (C37646/01)

9. The circuit of control amplifier type 1 consists of three long-tailed pair amplifying stages, a cathode-follower buffer stage and a cathode-follower output stage which supplies the control voltage to the grids of the series power valves. The reference voltage is supplied from a potential-divider connected across the +300V and -300V supplies; consequently, the +300V supply voltage variations are referenced to the -300V supply line, which is stabilized with reference to a neon voltage stabilizer valve (para. 14).

10. Input to the control amplifier is obtained from the junction of precision resistors R1 and R2 which are of equal value and are connected to the +300V and -300V control points. Any voltage variation about the earth potential is amplified by the long-tailed pair amplifying stage of V1 (6057); the grid of V1b is referenced to earth potential, or, if drift correction is employed, this grid is connected to the drift control output circuits. Capacitor C3 is connected between the anodes of V1 to suppress any transient signals.

11. Anti-phase signals from the anodes of V1 are amplified by long-tailed pair stage of V2 (6060) which feeds the buffer cathode follower stage of V3 (6060). The d.c. level of the signals is reduced by potential divider circuits in the cathodes of V3; small value capacitors C5 and C6 shunt resistors R16, R18 to restore the h.f. response of the stage.

12. Long-tailed pair V4 (6060) provides further amplification of the error signal and feeds one phase only to the output cathode-follower stage of V5 (6060). Both halves of V5 are connected in parallel, and the output to the grids of the series power valves is taken from the common-cathode resistor R28. The anodes of V5 and V4b are supplied from the unregulated +400V supplies to obtain a d.c. output level of approximately +250V necessary for correct biasing of the power valves.

Control amplifier type 2 circuit (C37647/01)

13. The basic circuit of control amplifier type 2 is similar to that of amplifier type 1 with the exception of the input circuit, valve references, component values and h.t. supply to the anode of the output stage drive (V5b).

14. Input error signal is obtained from a potential-divider, R1, R2, RV1 and R3, which is connected between the +300V and -300V lines. The junction of R1 and R2 is stabilized to +83V, with respect to earth, by neon stabilizer valve V1 (83A1); consequently, the input signal to V2a contains voltage errors present only in the -300V supply line.

15. The circuit of V3 to V6 is similar to the circuit of amplifier type 1 except for minor changes in component values and h.t. supply to V5b (from the +300V supply line).

Voltage regulator type 23 circuit (C37644/01)

16. The circuit of the -500V voltage regulator type 23 unit consists of a valve rectifier, a series valve and a long-tailed pair ripple-amplifier stage. The amplifier is referenced to the -300V supply line; the output is 200V d.c.

17. The 300V a.c. output of transformer TR1 is full-wave rectified by V1 (6X4) and applied to the series power valve V2 (EL91). The cathode of this valve is connected directly to the -300V supply line; thus, the negative output, which coincides with the centre-tap of the secondary winding on TR1, establishes the potential of the -500V supply line.

18. Regulating valve (V2) is controlled by V3 (6057). The grid of V3a receives a fixed, preset, bias from the potential-divider network comprising resistors R5, R3, RV1 and R4 which are connected across the -500V supply lines. Capacitor C2 ensures that the full a.c. content of the -500V line is applied to V3a grid. Potentiometer RV1 is preset for the required -500V output potential. The grid of V3b obtains a fixed d.c. bias from the junction of resistors R10 and R11 which form a potential-divider across the -200V regulated output. Capacitor C3 applies the full a.c. content of the -300V line to the grid of V3b to ensure that the -500V output depends on the -300V line output variations. The grid of V2 is connected via R2 to the anode of V3b. Capacitor C4 provides smoothing of the stabilized output.

External power supplies

19. The 45c/s to 65c/s power supply, required by the voltage regulator unit, is nominal 240V at 6·8A; total power dissipation is 1·7kW. The regulator functions satisfactorily within input variations of up to +5 per cent and -10 per cent from nominal voltage. Transformer primary-winding connections for the permissible range of the a.c. input voltages are given in Table 1.

TABLE 1

Transformer primary tap connections

External a.c. supply voltage:	TR1 connections: Live:	TR1 connections: Neutral:	TR2 connections: Live:	TR2 connections: Neutral:
200V	Q	K	B	D
210V	G	K	A	D
220V	Q	T	B	E
230V	G	T	A	E
240V	Q	N	B	F
250V	G	N	A	F

20. Power requirements of the type 1 control amplifier are as follows:

(1) 6·3V a.c. (earth level) - 1·2A
(2) 6·3V a.c. (+300V level) - 0·3A
(3) +300V d.c. (regulated) - 5mA
(4) -300V d.c. (regulated) - 9mA
(5) +400V d.c. (from fuse FS1) - 4mA.

21. Power requirements for the type 2 control amplifier are as follows:

(1) 6·3V a.c. (earth level) - 1·2A
(2) 6·3V a.c. (+300V level) - 0·3A
(3) +300V d.c. (regulated) - 11mA
(4) -300V d.c. (regulated) - 14mA
(5) +100V d.c. (from fuse FS2) - 1·1mA.

22. Power requirements for the type 23 voltage regulator are as follows:

(1) 6·3V a.c. (-300V level) - 1·1A
(2) -300V d.c. - 3mA
(3) 235V a.c. (from TR1) - 8·7A.

Performance details

23. Performance of the type 22G voltage regulator is as follows:

(1) Output accuracy:

(a) +300V at 1A to within ±0·25 per cent of the -300V supply potential

(b) -300V at 1A to within ±0·01 per cent
(c) -500V at 8mA to within ±0·02 per cent.

(2) Output ripple:

(a) +300V, less than 8·5mV peak-to-peak
(b) -300V, less than 8·5mV peak-to-peak
(c) -500V, less than 25mV peak-to-peak.

(3) Output adjustment:

(a) The -300V output potential can be adjusted by means of RV1 on control amplifier type 2; the control is accessible through a hole, labelled 300V, in the front panel of the main unit.
(b) The -500V output potential can be adjusted by means of RV1 on voltage regulator type 23; the control is accessible through a hole, labelled 500V, in the front panel of the main unit.

24. Performance of the type 1 control amplifier is as follows.

(1) Random drift rate: less than 300mV in 1000 hours
(2) Open loop d.c. gain: approximately 1800
(3) Maximum output voltage swing: +170V to +300V
(4) Output impedance: approximately 500 ohms.

25. Performance of the type 2 control amplifier is as follows:

(1) Random drift rate: less than 1·5V in 1000 hours. 0·6V in 15 hours
(2) Open loop d.c. gain: approximately 1300
(3) Maximum output voltage swing: 0V to -130V
(4) Output impedance: approximately 500 ohms.

26. Performance of the type 23 voltage regulator is as follows:

(1) Output: -200V at 2mA
(2) Output ripple: less than 7mV r.m.s.; ripple on the -500V line is the sum of the -300V line ripple and the -200V line ripple
(3) Output impedance: approximately 50 ohms.

Voltage checks

27. Typical off-load valve-voltages are listed in Tables 2, 3, 4 and 5 and provide a useful check when fault finding. The voltages are measured with respect to earth using a multimeter; the sub-chassis are mounted on the main chassis and connected to the main chassis circuits.

TABLE 2

Valve voltages, main chassis

Valve:	Pin No.:	Voltage measured:
V1 to V8 (6080)	2, 5 (anodes)	+445V to +482V
	1, 4 (grids)	+170V to +230V
	3, 6 (cathodes)	+300V
V9 to V16 (6080)	2, 5 (anodes)	+145V to +182V
	1, 4 (grids)	-70V to -130V
	3, 6 (cathodes)	0V

TABLE 3

Valve voltages, control amplifier type 1

Valve:	Pin No.:	Voltage measured:
V1a, b (6057)	1, 6 (anodes)	+100V to +120V
	2, 7 (grids)	0V
V3a, b (6060)	3, 8 (cathodes)	+180V to +220V
V4a (6060)	6 (anode)	+300V
	8 (cathode)	+65·5V to +95·5V
V4b (6060)	1 (anode)	+168V to +229V
	3 (cathode)	+65·5V to +95·5V
V5 (6060)	3, 8 (cathodes)	+170V to +230V

TABLE 4

Valve voltages, control amplifier type 2

Valve:		Pin No.:	Voltage measured:		
V1	(83A1)	1 (anode)	+82V	to	+84V
		2 (cathode)	0V		
V2a, b	(6057)	1, 6 (anodes)	+110V	to	+120V
		2, 7 (grids)	0V		
V4a, b	(6060)	3, 8 (cathodes)	+180V	to	+220V
V5a	(6060)	6 (anode)	-72V	to	-131V
		8 (cathode)	-193·5V	to	-201·5V
V5b	(6060)	1 (anode)	-72V	to	-131V
		8 (cathode)	-193·5V	to	-201·5V
V6	(6060)	3,8 (cathodes)	70V	to	-130V

TABLE 5

Valve voltages, voltage regulator type 23

Valve:		Pin No.:	Voltage measured.		
V2	(EL91)	5 (anode)	-220V	to	-188V
		7 (screen grid)	-220V	to	-188V
		1 (grid)	-303V	to	-309V
		2 (cathode)	-300V		
V3a	(6057)	1 (anode)	-300V		
		2 (grid)	-417V	to	-423V
V3b	(6057)	6 (anode)	-303V	to	-309V
		7 (grid)	-418V	to	-422V

Test procedure

28. The test procedure of the voltage regulator type 22G includes checks on the accuracy of the regulated outputs, on the effects of load variations and on parasitic oscillations. Tests of the main chassis circuit are performed with the control amplifiers installed on the main chassis.

Note...
It is important to ensure that both control amplifiers are tested individually prior to their installation on the main chassis. Voltage regulator type 23 is tested only when mounted on the chassis.

Control amplifier type 1

29. Tests of the control amplifier type 1 include checks of the stability of the output, and of amplifier gain. The following test equipment is required:

(1) Multimeter (calibrated against a sub-standard instrument prior to the tests)
(2) Oscilloscope
(3) D.C. valve voltmeter
(4) 1·5V dry-cell battery
(5) One 10-kilohm potentiometer
(6) One 50-kilohm potentiometer
(7) One 180-kilohm, ±1 per cent resistor
(8) One 330pF, 500V d.c. capacitor
(9) One on/off toggle switch.

30. Connect the required power supplies to the amplifier and connect the test circuit as shown in Fig. 1. Allow 2 to 3 minutes for the valves to warm-up before switching on the h.t. supplies.

31. Adjust RV1 (in the test circuit) to obtain +250V at the amplifier output, PL1/11. Observe the output waveform displayed on the oscilloscope and check that the output is free from any instability or oscillations.

32. Check that the valve voltages are as stated in Table 3 with the exception of the following voltages:

V4b	pin 1 (anode)	+250·5V to +253·5V
V5	pin 3, 8 (cathodes)	+252V to +255V.

33. Operate switch S1 (in the test circuit) and check that the output voltage at PL1/11 increases to +300V; note the change in the reading of the valve voltmeter. The ratio

of the voltage change at the amplifier output PL1/11 to the change in input voltage must not be less than 20 000 : 1.

Note...

Adjust RV2 (in the test circuit) to obtain a sufficiently sensitive range of the valve voltmeter for the measurements. In some instances it may be necessary to reverse the polarity of the battery.

Control amplifier type 2

34. Tests of the control amplifier type 2 include checks of the stability of the output, and of amplifier gain. The following test equipment is required:

(1) Multimeter (calibrated against a sub-standard instrument prior to the tests)
(2) Oscilloscope
(3) D.C. valve voltmeter
(4) 1·5V dry-cell battery
(5) One 10-kilohm potentiometer
(6) Two 100-kilohm, ±1 per cent resistors
(7) One 0·005μF, 350V d.c. capacitor.

35. Connect the required power supplies and connect the test circuit as shown in Fig. 2. Allow 2 to 3 minutes for the valves to warm-up before switching on the h.t. supplies.

36. Connect the multimeter between PL1/14 and earth, and adjust RV1 (on the unit) until zero volt potential is indicated on the most sensitive range of the multimeter. Remove the multimeter and connect PL1/14 to earth. Reconnect the multimeter as shown in test circuit.

37. Check that the amplifier output voltage is -50V ±2V. Adjust RV1 (in the test circuit) to obtain precisely -50V at PL1/11. Check that the amplifier output waveform (displayed on the oscilloscope) is free from any instability or oscillations.

38. Check that the valve voltages are as stated in Table 4 with the exception of the following voltages:

V5b	pin 1 (anode)	-50·5V to -53·5V
V6	pin 3, 8 (cathodes)	-49V to -51V.

39. Adjust RV1 (in the test circuit) to obtain a 10V change of the amplifier output voltage. The ratio of the voltage change at the amplifier output PL1/11 to the change of input voltage must not be less than 3000 : 1.

Main chassis

40. Ensure that the previously tested control amplifiers type 1 and 2 are firmly mounted on the main chassis and are correctly interconnected.

Note...
Remove voltage regulator type 23 if fitted.

The following test equipment is required:

(1) Multimeter
(2) Oscilloscope
(3) Two 300-ohm, 300-watt load resistors
(4) One 68-kilohm, 1-watt load resistor (or parallel-connected 100-kilohm and 150-kilohm, 0·5-watt resistors).

41. Link the following pins of the output socket (SKT1) to provide control voltages for the amplifiers:

(1) SKT1/5 to SKT1/1
(2) SKT1/3 to SKT1/7 and to SKT1/4
(3) SKT1/2 to SKT1/6.

42. Check that S1 (on the unit) is in the off position, and adjust the taps on transformers TR1 and TR2 to suit the mains voltage; connect the mains neutral line to PL3/13, and the mains live line of 200 to 250V, 45 to 65c/s, to PL3/14 and /15. The mains input must be within ±1 per cent of the nominal value indicated in Table 1 and the connections and input fuses must be capable of supplying a maximum current of 8·2A.

43. Ensure that the valves heaters are on for at least 2 to 3 minutes. Set switch S1 (on the unit) to the on position and check, with the multimeter, that the +300V output is present between SKT1/5 and SKT1/6, and the -300V output between SKT1/6 and SKT1/7. If necessary, adjust the negative output exactly to -300V by means of RV1 on control amplifier type 2, and check that the +300V output is within 0·25 per cent of the -300V line output.

44. Check that the valve voltages, measured with respect to earth, are as tabulated in Tables 2, 3 and 4.

45. Connect one 300-ohm, 300-watt load resistor between SKT1/5 and SKT1/6; connect the other 300-ohm, 300-watt load resistor between SKT1/6 and SKT1/7. Check with the multimeter that the loads effect on the output potentials does not exceed approximately 10mV.

46. With the loads connected to the 300V outputs, measure on the oscilloscope the ripple of the respective outputs; the ripple, in each instance, must not exceed 8·5mV peak-to-peak. Check that the output waveforms are free from any instability or oscillations.

47. With the loads connected, check the potentials across C1 and C2. The voltages measured must be within +384V to +416V.

48. Remove fuses FS1 and FS2 and check that the outputs fall to 0V.

49. Set switch S1 to off and refit the fuses.

Voltage regulator type 23

50. On completion of the main chassis tests, set switch S1 to on and check that the following potentials appear at the following pins of socket SKT1 into which the voltage regulator type 23 is normally plugged:

(1)	Between pins 13 and 11	-	227V to 235V, 50c/s
(2)	Between pins 11 and 9	-	227V to 235V, 50c/s
(3)	Between pins 8 (positive) and 4	-	-300V d.c.
(4)	Between pins 1 and 2	-	6·4V, 50c/s.

51. Set switch S1 to off, switch off the external power supply and install the voltage regulator type 23 on the main chassis. Switch on the external power supply and allow reasonable time for the valves to warm-up. Set switch S1 to on, and with the multimeter measure the -500V output between SKT1/6 and SKT1/8. Adjust RV1 (on type 23 regulator) to obtain exactly -500V across the output.

52. Connect the 68-kilohm resistor across the -500V output to obtain a 7·5mA output current. Check that the output voltage does not change more than 0·2V. Check that the output ripple, with the 7·5mA load connected, does not exceed 25mV peak-to-peak.

53. With the multimeter connected between earth and the respective valve pins, check that the potentials are as listed in Table 5.

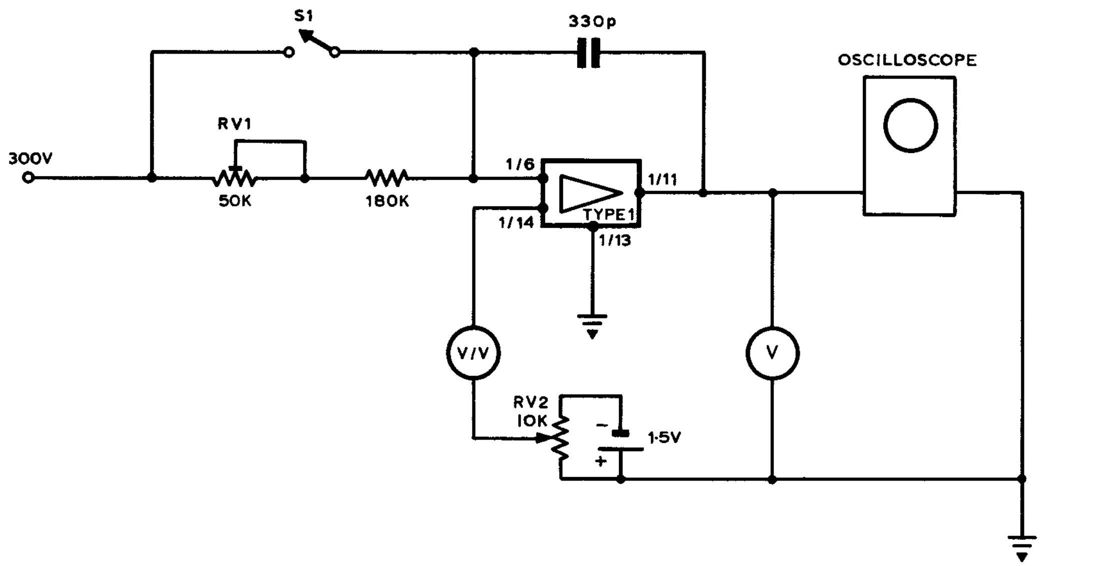


Fig. 1 Control amplifier type 1 – test circuit

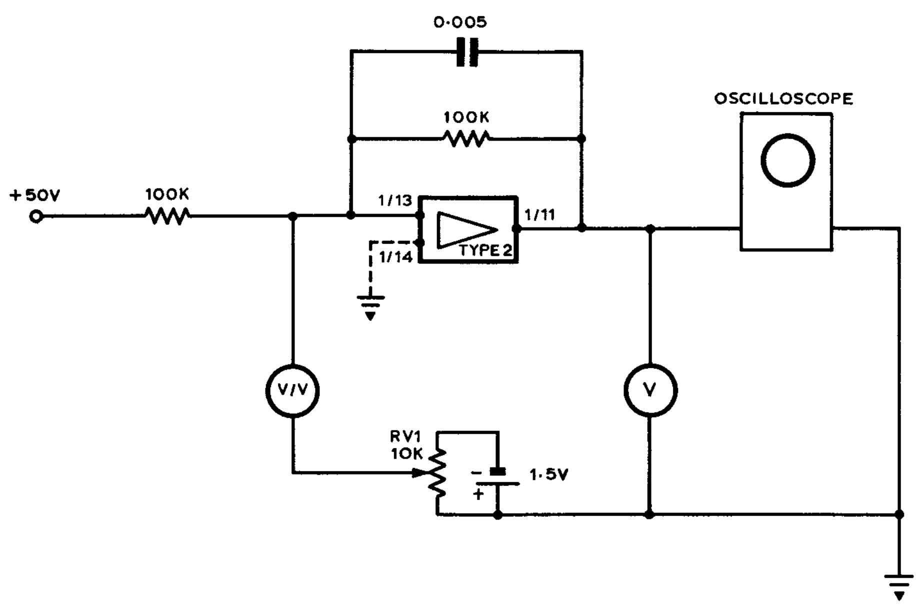


Fig. 2 Control amplifier type 2 – test circuit

Chapter 5B

VOLTAGE REGULATOR TYPE 28A

List of Contents

List of Tables

List of Illustrations

General

1. The voltage regulator unit type 28A supplies the regulated +50V and -50V signal voltages, at 1A, from a single-phase a.c. mains input of 200V to 500V, 45c/s to 65c/s.

2. The regulator unit contains the h.t transformer, heater transformer, bridge rectifiers, series valves for the +50V and -50V supplies, and three plug-in sub-chassis: two of the sub-chassis are fitted with control amplifiers for the series valves, the third sub-chassis contains two drift corrector circuits for the control amplifiers.

3. The regulation of the 50V supplies must be of high-stability to ensure that stable signal voltages are available for the computing circuits of the simulator; this is achieved by standard regulator circuits which employ series power-valves controlled by high-gain drift-corrected amplifiers.

4. The two control amplifiers obtain their control voltages from the load circuits to eliminate the effect of the voltage drop, due to the resistance of the rack wiring, on the voltage output of the regulators.

Main chassis circuit (B208516/01)

5. The primaries of the heater and h.t. transformers are supplied with a nominal a.c. voltage of 230V. The heater transformer T2 is fed directly from the instantaneous a.c. supply of the power distribution system; the h.t. transformer T1 is supplied from the delayed a.c. supply to ensure that the regulator heater supplies are switched on before the h.t. supplies. Manual control of h.t. is provided by switch S1.

6. The secondary windings of T1 supply two similar bridge-rectifier circuits, MR1 to MR4 inclusive, and MR5 to MR8 inclusive. The rectified output is smoothed by capacitors C1 and C2, and is supplied via independent fuses to the anodes of the series power valves. The grids of the series valves are controlled by the respective control amplifiers and their regulated output is smoothed and applied to internal loads which ensure that the minimum load is 17 per cent of the maximum output current to prevent operation of the valves near extreme cut-off condition.

7. The heater transformer T2 provides four 6·3V secondary outputs that are at various d.c. potentials for use in the respective stages in the main chassis circuit and in the sub-chassis.

8. The +300V and -300V regulated supplies are also routed, via the main chassis, to the two control amplifiers to provide h.t. for the amplifier valves.

Control amplifier type 9 circuit (C37805/01)

9. The circuit of the control amplifier type 9 is mounted on a sub-unit which contains three long-tailed-pair amplifying stages, a cathode-follower buffer stage and a cathode-follower output stage that supplies the control voltage to the grids of the series power valves. The reference voltage is obtained from a potential-divider connected across the +50V and -50V supplies to ensure that the +50V supply voltage variations are referenced to the -50V supply line, which is stabilized with reference to a neon voltage-stabilizer valve (para.13).

10. Input to the control amplifier is obtained from the junction of precision resistors R1 and R2 which are of equal ohmic value and are connected to the +50V control point and the -50V line. Any voltage variation about the earth potential is amplified by the long-tailed pair amplifying stage of V1 (6057); the grid of V1b is referenced to earth potential, or, if drift correction is employed as in the type 28A voltage regulator, the grid is connected to the drift-control output circuits. The drift corrector input is obtained from the junction of R1 and R2. Capacitor C3 and resistor R31 are connected between the anodes of V1 to suppress any fast, transient signals.

11. Anti-phase signals from the anodes of V1 are amplified by long-tailed pair stage of V2 (6060) which feeds the buffer cathode-follower stage of V3 (6060). The d.c. level of the signals is reduced by potential-divider circuits in the cathodes of V3; small capacitance-value capacitors C5 and C6 shunt resistors R16, R18 to restore the h.f. response of the stage.

12. Long-tailed pair V4 (6060) provides further amplification of the error signal, and feeds one phase only to the output cathode-follower stage of V5 (6060). Both halves of V5 are connected in parallel, and the output to the grids of the series power valves is taken from the common-cathode resistors R28, R30. The anodes of V5 are supplied from the unregulated +150V supplies to obtain the d.c. output level of approximately 0V necessary for correct biasing of the power valves. The V4 heater connections are tied via resistor R5 to the potential of the cathode of V4 to reduce the cathode-heater potential.

Control amplifier type 10 circuit (C37806/01)

13. The circuit of control amplifier type 10 is basically similar to the type 9 amplifier. The input error signal is obtained from a potential-divider network of R1, R2, RV1 and R3, which is connected between the +300V line and the -50V control point. The junction of R1 and R2 is stabilized to 83V, with respect to 0V, by neon stabilizer valve V1 (83A1); consequently, the input signal to V2 contains errors only in the -50V supply line.

14. The remaining circuit of the control amplifier type 10 is similar to the circuit of amplifier type 9 except for minor changes in component values, valve references, etc. The heaters of V5 are connected to the heaters of V4, in type 9 amplifier, and their level is established by the potential of the cathode of this valve (V4).

Control amplifier type 5 (C37675/01)

15. The control amplifier type 5 sub-chassis contains two similar drift corrector circuits of the mechanically-modulated amplifier type. The inputs of the drift correctors are connected to the grid circuits of the first amplifying valve of the respective control amplifier, and the drift corrector output is connected to the grid of the second half of the first amplifying valve. Thus any drift present at the first amplifier stage is reduced by the drift corrector output which is applied in opposition to the second half of the first stage (of the control amplifier) which then operates as a differential amplifier and produces a drift-corrected output.

16. The circuit of one section of the drift corrector consists of a two-stage amplifier. The d.c. input signal is modulated at 50c/s by contact sets of polarised, a.c.-fed relay RL1; the resulting square-wave is amplified by the cascade-connected amplifier consisting of the two halves of V1 (6057). The output is demodulated by the second contact of RL1/2; this ensures that the output is demodulated in anti-phase which is necessary for the circuit application of the drift corrector. Smoothing of the demodulated output is achieved by a filter consisting of R17 and C11, C13. The coil of relay RL1 is energized by 6·3V heater voltage from transformer T2 (main chassis).

External power supplies

17. A nominal supply of 230V at 1A is required for the voltage regulator type 28A.

18. The transformer T1 and T2 primary connections, for the permissible range of the a.c. input voltages, are detailed in Table 1.

TABLE 1

Transformer primary tap connections

External a.c. supply voltage:	T1 and T2 connections: Line:	Neutral:
200V	B	D
210V	A	D
220V	B	E
230V	A	E
240V	B	F
250V	A	F

19. Power requirements of the type 9 and type 10 control amplifiers are as follows:

(1) 6·3V a.c. (earth level) - 0·9A
(2) 6·3V a.c. (+300V level) - 0·3A
(3) 6·3V a.c. (at V4 cathode potential, type 9) - 0·3A
(4) +300V d.c. (regulated) - 7mA
(5) -300V d.c. (regulated) - 8mA
(6) (a) type 9: +150V d.c. (from FS1) - 5mA
(b) type 10: +100V d.c. (from FS2) - 5mA.

20. Power requirements of the type 5 control amplifier are as follows:

(1) 6·3V a.c. (earth level) - 0·61A
(2) +300V d.c. (regulated) - 4mA.

Performance details

21. Performance of the type 28A voltage regulator is as follows:

(1) Output accuracy:

(a) +50V at 1A to within 0·25 per cent of the -50V supply potential
(b) -50V at 1A to within 0·01 per cent.

(2) Output ripple:

(a) +50V, less than 8mV peak-to-peak
(b) -50V, less than 8mV peak-to-peak.

(3) Output adjustment of the -50V output potential may be set to within 0·01 per cent by potentiometer RV1 on control amplifier type 10; the control is accessible through the front panel of the main unit and is labelled 50V.

22. Performance of the type 9 control amplifier is as follows:

(1) Random drift rate: less than 300mV in 1000 hours
(2) Open d.c. loop gain: approximately 3500
(3) Maximum output voltage swing: ±50V
(4) Output impedance: less than 250 ohms.

23. Performance of the type 10 control amplifier is as follows:

(1) Random drift rate: less than 350mV in 1000 hours
(2) Open d.c. loop gain: approximately 3300
(3) Maximum output voltage swing: 0V to -100V
(4) Output impedance: less than 250 ohms.

24. The open d.c. loop gain of the type 5 control amplifier is approximately 750.

Voltage checks

25. The typical valve voltages are detailed in Table 2, 3, 4 and 5. The valve voltages are measured with respect to earth and with the equipment operating without external loads.

TABLE 2

Valve voltages, main chassis

Valve:	Pin No.:	Voltage measured:
V1 to V8 (6080)	2, 5 (anode)	+135V to +165V
	1, 4 (grid)	+4V
	3, 6 (cathode)	+50V
V9 to V16 (6080)	2, 5 (anode)	+ 90V to +110V
	1, 4 (grid)	-58V
	3, 6 (cathode)	0V

TABLE 3

Valve voltages, control amplifier type 9

Valve:		Pin No.:	Voltage measured:
V1a, b	(6057)	1, 6 (anode)	+111V to +124V
		2, 7 (grid)	0V
V2a, b	(6060)	1, 6 (anode)	+188V to +208V
V3a, b	(6060)	3, 8 (cathode)	+190V to +210V
V4a, b	(6060)	3, 8 (cathode)	-137V to -151V
V5a, b	(6060)	1, 6 (anode)	+135V to +165V
		3, 8 (cathode)	+3·8V to +4·2V

TABLE 4

Valve voltages, control amplifier type 10

Valve:		Pin No.:	Voltage measured:
V1	(83A1)	1 (anode)	+81·5V to +84·5V
		2 (cathode)	0V
V2a, b	(6057)	1, 6 (anode)	+109V to +121V
V3a, b	(6060)	1, 6 (anode)	+189V to +209V
V4a, b	(6060)	3, 8 (cathode)	+191V to +211V
V5a, b	(6060)	3, 8 (cathode)	-186V to -206V
V6a, b	(6060)	1, 6 (anode)	+90V to +110V
		3, 8 (cathode)	-55V to -61V

TABLE 5

Valve voltages, control amplifier type 5

Valve:		Pin No.:	Voltage measured:
V1, 2	(6057)	1, 6 (anode)	+90V to +130V
		3, 8 (cathode)	+1·4V

Test procedure

26. The following test procedure of the voltage regulator type 28A includes checks on the accuracy of the regulated outputs, on the effect of load variations, and checks on parasitic oscillations. The three sub-units are tested, individually, prior to their installation on the main chassis.

Control amplifier type 9 tests

27. Tests of the control amplifier type 9 sub-unit include checks of the stability of the output, and of amplifier gain. The following test equipment is required:

(1) Multimeter calibrated against a laboratory-standard instrument prior to the tests
(2) Oscilloscope
(3) D.C. valve voltmeter
(4) One 1·5V dry-cell battery
(5) One 60V dry-cell battery
(6) One 100-kilohm potentiometer
(7) One 10-kilohm potentiometer
(8) One 2μF, 250V capacitor
(9) One 27-ohm, ±10 per cent, 0·5-watt resistor.

28. Connect the required power supplies (para.19) to the amplifier and connect the test circuit as shown in Fig.1. Connect PL2/13 to PL1/1 and to earth; link PL1/11 and PL1/14. Allow 3 minutes for the valves to warm-up before switching on the h.t. supplies.

29. Adjust RV1 (in the test circuit) to obtain a +4V reading on multimeter M1 connected between PL1/14 and earth.

30. Check that the valve voltages are as stated in Table 3.

31. Adjust RV1 (in the test circuit) to obtain a zero volt reading on the multimeter, M1; when a steady 0V output is indicated, adjust RV2 (in the test circuit) to obtain a 0V reading on the valve voltmeter, M2. The amplifier gain is given by the following formula:

$$\text{Gain} = \frac{50\text{V}}{\text{M2 reading}}$$

Repeat this procedure at least 5 times and average the results; the resulting amplifier gain ratio must not be less than 6000:1.

32. Monitor the output waveform, displayed on the oscilloscope, throughout the tests and check that the amplifier output is free from instability or oscillations.

Control amplifier type 10 tests

33. Tests of the control amplifier type 10 sub-unit include checks of the stability of the output, and of amplifier gain. The following test equipment is required:

(1) Multimeter calibrated against a laboratory-standard instrument prior to the tests
(2) Oscilloscope
(3) D.C. valve voltmeter
(4) One 1·5V dry-cell battery
(5) One 60V dry-cell battery
(6) One 100-kilohm potentiometer
(7) One 10-kilohm potentiometer
(8) One 8μF, 250V capacitor
(9) One 47-ohm, ±10 per cent, 0·5-watt resistor
(10) Two 1-megohm, ±1 per cent resistors.

34. Connect the required power supplies (para.19) to the amplifier; remove all valves except V1 from the sub-unit and switch on the supplies. Connect a supply of -50V ±1 per cent to PL1/8; this supply can be obtained from wiper of the 100-kilohm potentiometer which is fed from the 60V dry-cell battery (the current drawn is 300μA). Check that the voltage at PL1/4 can be varied ±300mV (minimum) by adjustment of RV1 (on the amplifier). Set RV1 (on the amplifier) to obtain 0V at PL1/4. Remove the -50V supply from PL1/8 and earth PL1/4. Switch off the power supplies, connect the test circuit as shown in Fig.2, and replace all valves Switch on the l.t. supplies and allow 3 minutes for the valves to warm-up before switching on the h.t. supplies.

35. Adjust RV1 (in the test circuit) to obtain a reading of -58V on multimeter M1. Adjust RV2 (in the test circuit) to obtain a 0V reading on the valve voltmeter, M2.

Note...
To achieve 0V reading on M2, it may be necessary to reverse the polarity of the 1·5V battery.

36. Check that the valve voltages are as stated in Table 4,

37. With M1 indicating -58V at the amplifier output and M2 reading 0V, adjust RV1 (in the test circuit) to obtain a 0V reading M1 and note the indication of M2. The amplifier gain is given by the following formula:

$$\text{Gain} = \frac{58\text{V}}{\text{M2 reading}}$$

Repeat this test procedure at least 5 times and average the results; the average amplifier gain ratio must not be less than 4000: 1.

38. Monitor the output waveform, displayed on the oscilloscope, throughout the tests, and check that the amplifier output is free from instability or oscillations.

Control amplifier type 5 tests

39. Tests of the control amplifier type 5 sub-unit include checks on the amplifier gain and on residual output with the inputs earthed. The following test equipment is required:

(1) D.C. valve voltmeter calibrated against a laboratory-standard instrument prior to the tests
(2) Voltage-divider box
(3) One 12V dry-cell battery for the voltage-divider box supply
(4) One 1·5V dry-cell battery.

40. Link PL1/6 to PL1/7 and to PL1/12. Connect the required power supplies (para.20). Allow 10 minutes for the valves to warm-up before switching on the h.t. supplies.

41. Using the valve voltmeter check that the anode voltages of the valves are as stated in Table 5.

42. Remove the link from PL1/6. Connect the output of the voltage-divider box to PL1/6 and adjust the potential between PL1/6 and PL1/12 to 1mV. With the valve voltmeter measure the output between PL1/13 and PL1/12; the change in the output voltage, when the 1mV input is applied, must be between 500mV and 1200mV. The ratio of these two voltages represents the d.c. gain of the amplifier.

Note...
An appreciable time delay is built into the output circuit of the amplifier.

43. Repeat the test procedure detailed in para.42, but with the polarity of the input signal reversed.

44. Replace the link between PL1/6 and PL1/12 and remove the link between PL1/7 and PL1/12. Carry out the test procedure detailed in para.42 and 43 for the second section of the sub-unit. The output is measured, in this instance, between PL1/14 and PL1/12.

45. Disconnect the voltage-divider box and link PL1/6 and PL1/7 to PL1/12. With the valve voltmeter, measure the residual output between PL1/12 and PL1/13 (taking into account the delay through the amplifier). Divide this measured output by the gain measured in para.42. The result must not exceed 250μV.

46. Repeat procedure of para.45 for the second section of the sub-unit. Measure the output between PL1/14 and PL1/12.

Main chassis tests

47. Ensure that the previously tested amplifiers types 9, 10 and 5 are securely mounted on the main chassis and are correctly interconnected. The following test equipment is required:

(1) Multimeter calibrated against a laboratory-standard instrument prior to the tests
(2) Oscilloscope
(3) Two 50-ohm, 50-watt load resistors.

48, Link the following pins of the output socket (SKT1) to provide control voltages for the amplifier:

(1) SKT1/5 to SKT1/1
(2) SKT1/3 to SKT1/7.

49. Check that S1 is in the off position, and adjust the taps on T1 and T2 to suit the mains voltage (Table 1); connect the mains neutral line to PL2/9, and the mains line of 200 to 250V, 45 to 65c/s, to PL2/7 and PL2/11. The mains input must be within ±1 per cent of the nominal value indicated in Table 1.

50. Check that the valve heaters are on. Two minutes after connection of the mains supply to PL2/7, set switch S1 to the on position; check, with the multimeter, that the +50V output is present between SKT1/5 and SKT1/6, and the -50V output is available between SKT1/7 and SKR1/6. Adjust the negative output to exactly -50V and check that the +50V output is within 0·25 per cent of the -50V line output.

51. Check that the valve voltages, measured with respect to earth, are as detailed in Table 2, 3, 4 and 5.

52. Connect a 1A load resistor (50-ohm, 50-watt) between SKT1/5 and SKT1/6; connect the other 1A load resistor between SKT1/7 and SKT1/6. Check that the loads have no discernible effect on the output potentials. The normal change is approximately 10µV.

53. With the loads connected to the 50V outputs, measure the ripple on the respective outputs; the ripple, in each instance, must not exceed 8 mV peak-to-peak. Check that the output waveforms are free from any instability or oscillations.

54. With the loads connected, check the potentials across C1 and C2. The voltages measured must be within +150V ±3 per cent.

55. Remove both fuses and check that the outputs fall to zero V.

56. Set switch S1 to off and refit the fuses.

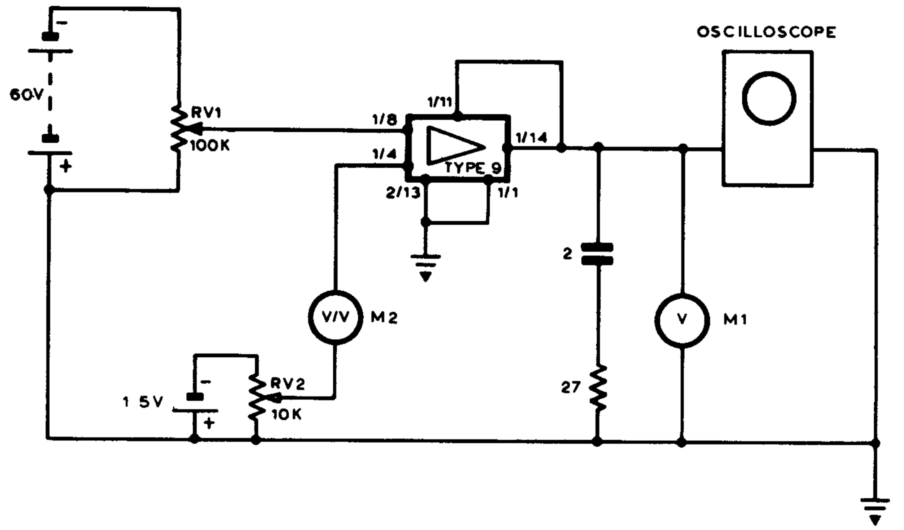


Fig 1 Control amplifier type 9 – test circuit

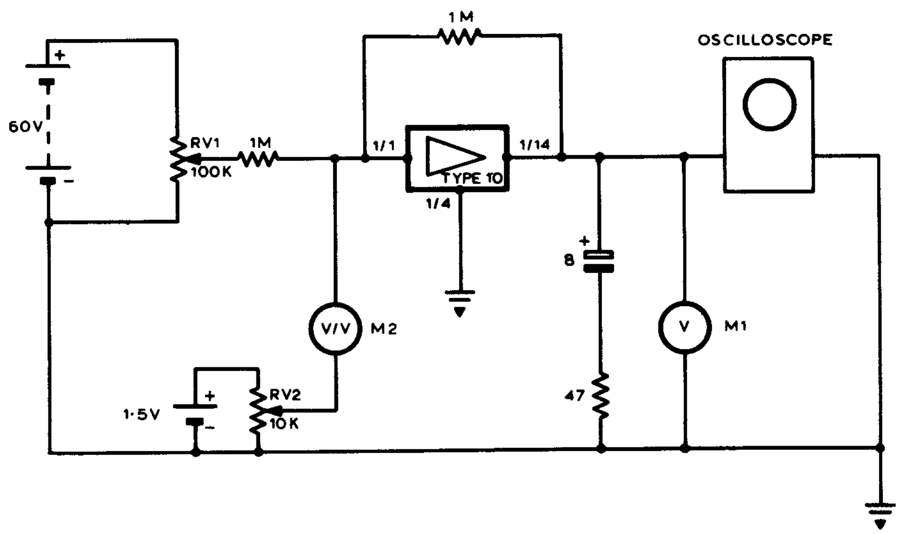


Fig 2 Control amplifier type 10 – test circuit

Chapter 5C

VOLTAGE CALIBRATOR TYPE 6A

List of Contents

List of Illustrations

General

1. Voltage calibrator type 6A provides a means of checking and calibrating the regulated d.c. power supplies of rack 11. A sensitive galvanometer, mounted on the front panel of the unit, indicates the result of the comparison between a selected supply and a standard reference voltage. The following regulated-supplies are checked by means of the calibrator unit:

(1) -500V d.c., within ±0·4 per cent
(2) +300V d.c., within ±0·2 per cent
(3) -300V d.c., within ±0·2 per cent
(4) +50V d.c., within ±0·1 per cent
(5) -50V d.c., within ±0·1 per cent.

Supplies detailed in sub-para.(2) to (5), inclusive, are compared with the terminal voltage of a standard cell; the -500V supply, sub-para.(1), is compared with a reference voltage derived from the external -300V regulated supply.

Circuit description

2. The circuit of the calibrator unit consists of a galvanometer, a standard cell, potential-divider-connected resistors and the associated supply-selector switch. When the mains are switched off, a relay disconnects the galvanometer circuit to prevent accidental discharge of the standard cell. Galvanometer sensitivity is varied in a ratio of approximately 10:1 by means of a three-position HIGH SENS/OFF/ LOW SENS switch S1 which is biased to the centre OFF position; in this position the galvanometer is disconnected from the standard cell. The galvanometer full-scale deflection of 4cms, from the centre position, is approximately equal to a supply variation of 1 per cent on the high-sensitivity range and approximately 10 per cent on the low-sensitivity range. The equivalent of a 1mm deflection corresponds to 0·024 per cent (HIGH SENS range).

3. The regulated supply voltages, fed via plug PL1, are each stepped down, by their respective potential-divider networks, to a value which can be compared against a standard reference of 1·0193V d.c. This reduced voltage is fed, via pole 7 of the supply selector switch S1(a) and operated contact set RL1/1, to the positive terminal of the galvanometer; relay RL1 is energized by the +28V d.c. supply when the delayed a.c. supply is available to the power units on rack 11.

4. The galvanometer negative terminal is connected, via resistor R14, sensitivity switch S2 (in the HIGH or LOW SENS position) and operated contact set RL1/2, to pole 1 of switch S1(a). Switch S1(a) completes the circuit either to the standard cell (BATT 1) or, when checking the -500V supply, to the reference voltage (1·0193V) at the junction of R11 and 12. Poles 2 to 5 of S1(a) and (c) connect the standard cell in the required polarity according to the polarity of the supply to be measured. Diodes MR1 and 2 provide overload protection of the galvanometer.

Calibrator operation

5. Normally, all preliminary measurements are made with S2 in the LOW SENS position, to prevent galvanometer damage in the event of a fault in the power supply system; if the registered error produces small deflections (below ±4mm), the error is measured accurately in the HIGH SENS position of S2. If the measured error exceeds the required limits, the corresponding power unit must be re-adjusted. When the selected supply voltage is exact, then the voltage, fed to the positive terminal of the galvanometer, equals the reference voltage at the negative terminal, and consequently, the galvanometer is not deflected.

Test procedure

6. The test procedure provides checks of the calibrator circuit, relay operation and potential divider accuracy. All tests are carried out on the bench using the following equipment:

(1) Multimeter
(2) Sub-standard d.c. voltmeter capable of measuring 500V, 300V and 50V to an accuracy of ±0·1 per cent.

7. Disconnect the standard cell (BATT 1) and galvanometer; ensure that shunt resistor R13 remains in the circuit. Connect a +28V d.c. supply to plug PL1/11 and /12 and check that relay RL1 is operated.

Circuit check

8. Connect the multimeter, set to a high-resistance range, to the standard-cell leads, i.e., to S1(c) 4 and 5. Check that the multimeter indicates an open-circuit for all positions of selector switch S1.

9. Set switch S2 to the LOW SENS position and check that the multimeter reads 35 300 ohms ±20 per cent for all positions of selector switch S1. Set switch S2 to the HIGH SENS position and check that the multimeter reads 2300 ohms ±10 per cent for all positions of switch S1.

Relay operation

10. Remove the 28V d.c. supply to relay RL1, set switch S2 to the HIGH SENS position and check that the multimeter now indicates an open circuit. Replace the 28V supply and set S2 to the OFF position.

Potential divider accuracy

11. Remove the multimeter, reconnect the standard cell and galvanometer, and set selector switch S1 to the OFF position. Connect the appropriate d.c. and a.c. supplies, earth and signal-return lines to plug PL1.

12. Connect the sub-standard voltmeter (50V d.c. range) between plug PL1/10 and /13 (positive) and adjust the -50V regulated supply as accurately as possible to 50V. Set selector switch S1 to the -50V position and set switch S2 to the LOW SENS position.

Check that the galvanometer indication is within ±1·0 division of the centre-zero mark If this is below the limit, set switch S2 to the HIGH SENS position and check that the galvanometer indicator is within ±1·75 divisions of the centre-zero mark.

13. Repeat the procedure detailed in para.12 for the remaining regulated supplies, first setting the supply voltages to the sub-standard voltmeter, and finally checking that the galvanometer indications are within the limits stated (para.1).

Chapter 5D

MAINS CONTROL PANEL

List of Contents

List of Illustrations

General

1. The mains control panel, mounted in rack 11, constitutes a central control point for the flight simulator a.c. supplies. The unit provides switching of the regulated a.c. mains supplies to the simulator, registers the hours-run of the equipment and contains a three-phase failure interlock circuit.

2. The front panel of the unit is fitted with start and stop push-buttons, an hour-meter and a neon indicator lamp V1; the lamp is connected in parallel with the hour-meter and, when lit, indicates that the delayed a.c. supplies are connected to the flight simulator.

3. Mounted inside the unit are the transformers of the three-phase failure circuit, an associated thermal overload cut-out switch and a relay of the delayed a.c. supply switching system.

Circuit description (C218085/01)

4. The mains control panel is connected to the electrical circuit of rack 11 via plugs PL1 and 2. The push-buttons and associated circuits control the operation of two contactors 11X/CR1 and /CR2 that are mounted in the side recess of rack 11, and through which all instantaneous and delayed a.c. power to the flight simulator is routed. The switching circuits of the control panel are connected in series with the flight simulator safety trip-circuit (Part 3, Chap.3), for which only phase A (red) is utilized.

L.T. control

5. The LT START push-button S3, when operated, connects phase A of the a.c. supply from the trip circuit (PL1/15) to the coil of contactor 11X/CR1 (/500), via plug PL1/3. The contactor is energized and remains held-in by its contact 11X/CR1/S1 which is connected between PL1/3 and /5, thus by-passing S3 and feeding the a.c. supply to the HT START button S1. Resistor R3, connected in parallel with S3, provides a common return for the neon indicators in the safety trip-circuit described in Part 3, Chap.3.

6. The LT STOP button S4, when operated, breaks the supply to S3 and to the instantaneous a.c. supply contactor 11X/CR1 which is consequently released.

H.T. control

7. When HT START button S1 is operated, the a.c. supply from contact set 11X/CR1/S1 (via PL1/3) is connected via the HT STOP button S2 to the coil of relay RL1. Operated contact set RL1/1, which is connected in parallel with S1, maintains RL1 in the operated state and feeds the a.c. supply, via plugs PL1/4 and /6, contact set 11X/CR2/S2 (/500) and PL1/1, to the heating-element of thermal delay switch X1.

8. The contact of switch X1 makes, after a nominal delay of 1 minute, and the a.c. supply is connected, via plug PL1/13, to the coil of h.t. contactor 11X/CR2. The a.c. supply from X1 is also fed to the indicator neon V1 and to the hour-meter M1 which commences to record the cumulative operating time of the flight simulator.

9. When the HT STOP button S2 is operated, the a.c. supply to contactor 11X/CR2 is removed and the delayed a.c. supplies are disconnected.

Three-phase failure protection

10. The three-phase failure protection circuit consists of three transformers T1, 2 and 3 and a thermal overload cut-out switch X2. The transformer primary windings are star-connected via plug PL2/1, /5, /9 and the associated fuses on the fuse and indicator panel (Part 3, Chap.3), to their respective phases. The common connection to the primary windings is returned via plug PL1/8, to the a.c. neutral return line. The secondary windings form a series-connected circuit which feeds the heating element of the thermal-overload cut-out switch X2. When all three phases are present, the resultant voltage across the switch heating element is zero volts.

11. Failure of one or two phases produces a voltage which heats the heating element causing the operated bi-metallic contact of switch X2 to break the circuit. When contact X2 operates, the a.c. supply to the mains control unit is disconnected and consequently the contactors and associated circuits are de-energized.

Test procedure

12. The tests of the mains control panel consist of checks on the operation of the thermal delay and overload switches, of the neon indicator V1, and resistance value check of resistor R1. A multimeter and a stopwatch are required for the tests.

13. Connect the required power supplies to the unit under test as follows:

(1) 230V (phase A) to PL1/3
(2) 230V (phase A) to PL2/1
(3) 230V (phase B) to PL2/5
(4) 230V (phase C) to PL2/9
(5) Three-phase neutral to PL1/8.

14. Link PL1/1 to PL1/4.

H.T. circuit

15. Operate the HT START push-button S1 and check the operation of delay switch X1 by measuring the time delay between the operation of the switch and neon V1 striking. Check that the hour-meter M1 is operating. Operate the HT STOP button S2, and check that neon V1 extinguishes and hour-meter M1 stops.

L.T. circuit

16. Connect the multimeter, set to 250V a.c. range, between PL1/15 and neutral, PL1/8. The meter will register a standing voltage across resistor R1. Operate the LT START push-button S3 and check that the meter registers 230V a.c. Release the push-button and ensure that the meter reading is reduced to the original reading.

17. Switch off the a.c. supplies and transfer the 230V (phase A) connection from PL1/3 to PL1/5. Switch on the a.c. supplies and check that the multimeter again reads 230V a.c. Operate the LT STOP push-button and check that the multimeter indication is reduced to zero volts.

Three-phase failure protection circuit

18. With the multimeter connected between PL1/15 and neutral (reading 230V a.c.), check the operation of the three-phase failure circuit by disconnecting, in succession, the "live" connections to PL2/1, /5 and /9. In each instance, the overload cut-out switch X2 must operate and the meter reading must reduce to zero volts. When all three "live" connections to PL2 pins are restored, the multimeter must indicate 230V a.c.

19. Disconnect the power supplies, the link and the multimeter from the unit under test.

Resistor R1

20. With the multimeter set to a 100 kilohms range, measure the resistance value of R1 by connecting the multimeter between PL1/3 and PL1/5. The indicated value must be 47 kilohms ±10 per cent.

Chapter 5E

RADIO AIDS FUSE AND SWITCH PANEL

List of Contents

List of Illustrations

General

1. The fuse and switch panel (24BE), mounted on the radio aids console, is fitted with eight fuses, corresponding indicator lamps and LT and HT switches which control the instantaneous a.c. supply to the power units of the radio aids systems.

Circuit (C218536/01, /340 and /341)

2. The following circuit components are fitted on the fuse and switch panel 24BE:

(1) LT ON/off switch S1
(2) HT ON/off switch S2
(3) Three fuses and lamps (FS1 to FS3 and V1 to V3 respectively) marked DC SUPPLIES

(4) Two fuses and lamps (FS4, FS5 and V4, V5) which are marked HEATERS 1 and HEATERS 2 respectively

(5) Three fuses and lamps (FS6 to FS8 and V6 to V8 respectively) marked AC 400c/s SUPPLIES

(6) Three relays and two thermal delay switches of the h.t. delay circuits (para. 6).

Switch and fuse circuits

3. When LT switch S1 is selected ON, it connects the instantaneous a.c. supplies to heater transformers 24BF/T3 and 22BE/T1 (/340) which supply the amplifier units of the radio aids systems. HT switch S2 controls a relay the contact sets of which connect the a.c. supply to the transformers of the d.c. power units. Switch S2 thus provides an overriding manual control of the automatic h.t. delay circuits which are included in this unit (para. 6).

4. The five fuses listed in para. 2 (3) and (4) are inserted in the "live" a.c. lines to the transformers of the ±250V, +28V d.c. power units (24BF), and to the transformers of the heater supplies. When a specific fuse ruptures, its corresponding lamp lights.

5. The three AC 400c/s SUPPLIES fuses are included in the 200V, 400c/s outputs of the Mackie motor-alternator (/341) which is controlled by separate switches. The corresponding lamps provide visual warning in the instance of a ruptured fuse.

H.T. delay circuits

6. The automatic h.t. delay circuits consist of two relays and two thermal switches, operated by the secondary outputs of the heater 1 and 2 supplies transformers, and a third relay operated by the flight simulator main HT START switch in series with the HT switch S2. The contact sets of these relays are inserted in the "live" supply lines to the d.c. power units.

7. When the LT switch S1 is set to ON, the secondary windings of the heater transformers 22BE/T1 and 24BF/T3 (/340) supply current to the heating elements of thermal delay switches 24BE/X1 and /X2 via released contact sets 24BE/RL1/2 and /RL2/2 respectively. After a nominal delay of one minute, the contacts of the delay switches /X1 and /X2 operate and energize relays 24BE/RL1 and /RL2; simultaneously the No. 2 contact sets of these relays change-over, thus energizing the coils of the two relays and disconnecting the heating elements of the delay switches from the circuit. Contact sets 24BE/RL1/1 and /RL2/1 are in series with contact set /RL3/1 (para. 8) in the phase 'A' of the a.c. supplies fed to the primary windings of the ±250V d.c. power unit transformers.

8. An additional delay interlock is provided by relay 24BE/RL3 which can be operated by the HT switch S2 when the main flight simulator HT START switch (on the mains control panel 11C, Chap.5D) is pressed. The three contact sets of this relay are included in the individual three phases which feed the d.c. and a.c. supplies of the radio aids systems.

Test procedure (C218536/01)

9. The fuse and indicator panel does not require any testing other than functional tests "in situ", such as the operation of the LT and HT switches, checks of the automatic delay time of delay switches X1 and X2, and operation of relays RL1, RL2 and RL3. A stopwatch is required for the tests.

Functional tests

10. Operate the simulator LT START switch, on panel 11C. Ensure that the LT and HT switches on the fuse and indicator panel are set to the off position. Remove the three DC SUPPLIES fuses (FS1, FS2 and FS3) and the two HEATERS (FS4 and FS5) fuses. Set the LT switch S1 to ON and ascertain that lamps V4 and V5 light. Switch off the power and refit fuses FS4 and FS5. Set both the LT and HT switches to ON and measure the time elapsed between the operation of the flight simulator HT START switch (on the mains control panel) and lamps V1, V2 and V3 lighting. The measured delay must be between 45 and 65 seconds.

Note...

The delay of lamps V1 and V2 may differ from the delay of lamp V3 due to the operation of the additional contact sets (RL1/1 and RL2/1) (para. 7).

11. Ensure that the 400c/s Mackie motor-alternator is operating. Remove fuses FS6, FS7 and FS8 and check that the corresponding lamps V6, V7 and V8 light.

12. Switch off all power supplies and refit all fuses.

Chapter 5F

±250V, +28V POWER UNIT

List of Contents

List of Tables

List of Illustrations

General

1. The ±250V, +28V d.c. power unit is a general purpose power supply unit which delivers positive and negative unregulated h.t. supplies, 6·3V heater supplies and a +28V d.c. general l.t. line output used for operation of relays, motors, lamps etc.

Circuit description (C99138/01)

2. The circuit of the ±h.t. supplies comprises two mains transformers, conventional bridge-rectifier and smoothing circuits. The mains transformers require an input of 230V, 45 to 65c/s. The positive and negative supplies are identical except for polarity of outputs and component references, and only the -250V supply circuit is described.

3. Bridge-rectifier MR1 to MR4, inclusive, provides rectification of the secondary-winding output of transformer T1; resistor R1 and capacitor C1 are connected in series across the secondary winding to suppress mains transients. The output of the bridge-rectifier is smoothed by capacitors C3a and C3b. Internal loading of the unregulated -250V d.c. output is provided by resistor R3.

4. The circuit of the +28V d.c. supply is similar to the ±250V d.c. circuit. Bridge-rectifier MR9 to MR12, inclusive, rectifies the output of transformer T4 secondary winding; the bridge output is smoothed by capacitors C5a to C5d; the internal load of the unregulated output is provided by resistor R5.

5. The 6·3V a.c. heater supplies are derived from the two secondary-windings of transformer T3. The No.1 secondary-winding output is at -250V level, the centre tap of the secondary-winding being connected to the -250V h.t. line. The No.2 secondary-winding output is at 0V (earth level).

Power supplies

6. The ±250V, +28V d.c. power unit requires four 230V, 45 to 65c/s, inputs which can be externally connected either to a common single-phase supply, or separately to a three-phase supply (transformers T3 and T4 are then parallel-connected). The power consumption, at full loading of each output, is as follows:

(1) Transformer T1 and T2 (each) - 5A
(2) Transformer T3 - 5A
(3) Transformer T4 - 5A.

Performance details

7. The outputs of the ±250V, +28V d.c. power unit are as follows:

(1) D.C. outputs:

(a) +250V d.c. unregulated at 2·5A
(b) -250V d.c. unregulated at 2·5A

(c) +28V d.c. unregulated at 10A.

(2) Two 6·3V a.c. outputs:

(a) 50A at -250V potential
(b) 7A at 0V potential (if wired).

Voltage checks

WARNING...
THE HEATER VOLTAGE (NO.1 SECONDARY WINDING OF TRANSFORMER T3) IS AT -250V D.C. LEVEL AND ADEQUATE PRECAUTIONS MUST THEREFORE BE ENFORCED WHEN MEASURING THIS POTENTIAL.

8. Voltages listed in Table 1 include potentials measured at the a.c. inputs and outputs of transformers T1, T2, T3 and T4 and at the power unit outputs. The transformer input voltages are measured, with a multimeter, with respect to supply neutral, the ±250V d.c. voltage checks are made with respect to 0V outputs which must be connected to earth, and the +28V d.c. voltage check is made with respect to power earth return. All voltages are measured at off-load conditions.

TABLE 1

Circuit voltages

Across component:	Voltage measured:
T1, T2 and T3 primary	230 ± 1V a.c.
T1 secondary	250 ±10V a.c.
T2 secondary	250 ±10V a.c.
T3 secondary No.1	6·3 ±0·3V a.c.
T3 secondary No.2	6·3 ±0·3V a.c.
T4 secondary	30 ± 3V d.c.
R3	-250 ±10V d.c.
R4	+250 ±10V d.c.
R5	+28 ± 3V d.c.

Test procedure

9. The following test procedure includes measurements of output voltages and checks on the ripple level present at the d.c. outputs.

10. The following test equipment is required:

(1) Multimeter
(2) Oscilloscope
(3) Two 100-ohm, 1-kilowatt resistors
(4) One 3-ohm, 500-watt resistor.

11. Ensure that the 0V outputs of the individual power supplies are linked to chassis earth. Connect the required power supply (para.6) to the unit under test and check that the circuit voltages are as stated in Table 1.

12. Switch off the external power supplies and connect the 100-ohm load resistors between earth and the +250V and -250V output terminals; connect the 3-ohm resistor between earth and the +28V output terminal. Switch on the external power supplies and, with the multimeter, check that the output voltages are within limits stated in Table 2.

TABLE 2

Output voltages

Across load resistors:	Output limits:
R3	-250 ± 10V
R4	+250 ± 10V
R5	+ 28 ± 3V

13. With the oscilloscope connected across the ±250V and +28V output terminals check that the output ripple does not exceed 30V peak-to-peak for the ±250V outputs, and 3·5V peak-to-peak for the +28V output.

14. With the multimeter check that the No.1 6·3V a.c. output of T3 is at -250V level and the No.2 output is at earth level (if wired).

Chapter 5G

115V, 26V 400C/S POWER UNIT

List of Contents

List of Tables

List of Illustrations

General

1. The 115V, 26V, 400c/s, power unit transforms a three-phase input of 200V, 400c/s, into a two-phase output of 115V, a quadrature (reference) phase at 115V, and a 26V output. The transformers provide isolation of the outputs from the inputs, and are suitably connected to produce the required outputs.

2. This power unit includes a 400c/s amplifier unit, mounted on a sub-chassis, that delivers an output of 40V, 400c/s, of accurate sinusoidal waveform. The 40V, 400c/s, amplifier is a standard unit described in this Part.

Circuit description (C99142/01)

3. The 'B' and 'C' phases of the 200V, 400c/s, three-phase input are connected to the primary of T1; the centre-tapped secondary winding of T1 produces the ϕ_1 and ϕ_2 phases at 115V, 400c/s. Transformer T2 is connected in a Scott circuit between the centre tap of the primary of T1 and phase 'A' of the 200V input; thus its secondary 115V output consists of a quadrature phase ($\phi_{Ref.}$) which is at 90^o to ϕ_1 and ϕ_2.

4. The primary of T3 is connected between the 400c/s common power earth return and the ϕ_2 output of T1; the secondary output of T3 is stepped-down to 26V at ϕ_2.

5. The 400c/s amplifier X1 is supplied with $\pm$250V h.t. and 6·3V heater supplies via terminals of TS2. The amplifier input, via PL1/2 and TS4, is fed with ϕ_1 from T1 secondary; the input earth return is routed via PL1/1 and TS3. The unit supplies two 40V, 400c/s, anti-phase signal outputs of accurate and harmonic-free waveform.

Power supplies

6. The 115V, 26V, 400c/s, power unit requires a three-phase input of 200V, 400c/s at 1kVA..

Performance details

7. The 115V, 26V, 400c/s, power unit provides the following 400c/s outputs:

(1) ϕ_1 - 115 $\pm$2V at 3A
(2) ϕ_2 - 115 $\pm$2V at 3A
(3) $\phi_{Ref.}$ - 115 $\pm$2V at 3A
(4) ϕ_2 - 26 $\pm$1V at 10A
(5) ϕ_A and ϕ_B (in anti-phase) - 40V at 50mA.

Voltage checks

8. The voltages listed in Table 1 represent off-load measurements at specified points. All voltages are measured with a valve voltmeter; the 200V, 400c/s, inputs

are measured between phases; the ϕ_1, ϕ_2 and $\phi_{Ref.}$ are checked with respect to the 400c/s power earth return which must be connected to the supply neutral during bench tests.

TABLE 1

Circuit voltages

Test points:	Phase:	Voltage measured:
TS1/1, TS1/2	A - B	200 ±2V
TS1/2, TS1/3	B - C	200 ±2V
TS1/1, TS1/3	A - C	200 ±2V
TS1/4, TS1/5	ϕ_1	115 ±2V
TS1/6, TS1/7	ϕ_2	115 ±2V
TS1/8, TS1/9	$\phi_{Ref.}$	115 ±2V
TS1/10, TS1/11	ϕ_2	26 ±1V

<u>Test procedure</u>

9. The following test procedure includes output voltage measurements and checks on the phase relationships of the outputs of the unit. The following test equipment is required:

(1) Oscilloscope
(2) Valve voltmeter
(3) Three 56-ohm, ±10 per cent, 60-watt resistors.

10. Ensure that the 400c/s power earth return is connected to the supply neutral; connect the required power supply (para.6) to the unit under test and, with the valve voltmeter, check that the voltages are as listed in Table 1.

11. Switch off the external power supplies and connect one 56-ohm load resistor between TS1/4 and TS1/5; connect the second 56-ohm load resistor between TS1/6 and TS1/7, and connect the third 56-ohm load resistor between TS1/8 and TS1/9. Switch on the external power supplies and check that the output voltages are as listed in Table 2.

TABLE 2

Output voltages

Terminals on TS1:	Output limits:
4 - 5	115 $\pm$2V
6 - 7	115 $\pm$2V
8 - 9	115 $\pm$2V
10 - 11	26 $\pm$1V

12. Connect the A1 and A2 inputs of the oscilloscope to TS1/4 and TS1/6 (ϕ_1 and ϕ_2 outputs), respectively, and connect the oscilloscope earth input to TS1/5 and TS1/7 (linked). Check that the ϕ_1 and ϕ_2 outputs are in anti-phase.

13. Disconnect the oscilloscope A1 input fron TS1/6 and connect to TS1/8 ($\phi_{Ref.}$); link TS1/9 to TS1/5 and TS1/7. Check that the $\phi_{Ref.}$ output phase is at 90° to ϕ_1 output. Disconnect the oscilloscope.

14. Connect the oscilloscope A1 input to TS1/6 and the A2 input to TS1/10. Check that the 26V output is in phase with the ϕ_2 output. Disconnect the oscilloscope.

15. Link TS2/7 to the common earth link, and with the oscilloscope A1 input connected to TS2/6, and the A2 input connected to TS2/8, check that the two outputs are in anti-phase and at 56·5 $\pm$0·5V peak-to-peak.

Chapter 5H

40V, 400C/S AMPLIFIER

List of Contents

List of Tables

List of Illustrations

General

1. The function of the 40V, 400c/s amplifier unit is to provide a 400c/s low-distortion signal power supply for a.c. systems where accurate computation and resolution of bearing angles and similar quantities is required. The amplitude of the output can be adjusted from 35V to 55V r.m.s.

Circuit description (B99143/01)

2. The 40V, 400c/s amplifier unit consists of a long-tailed pair phase-splitter, and a four-valve, parallel push-pull power output stage. Pentodes V1 and V2 (6059) form a long-tailed pair amplifier and phase-splitter at 400c/s by virtue of the cathode-coupling capacitor C4; the anti-phase outputs of the phase-splitter are fed via capacitors C5 and C6 to the output pentodes V3, V4, V5 and V6 (EL86).

3. The normal 115V, 400c/s input for the unit is fed to the grid of V1 via gain control RV1 and resistor R1. The output amplitude of the unit can be adjusted, by RV1, from 35 to 55V r.m.s. Negative feedback is applied to the grid of V1 from the secondary of output transformer T1, via resistor R2, to ensure low harmonic-distortion.

4. High-frequency decoupling is provided by the low-pass filter networks, C7, R12 and C8, R19, that are connected across the output stage grid-leak resistors R13 and R20; harmonic distortion is further reduced by the degeneration provided by the undecoupled cathode resistor R16 of the output stages. Capacitors C9 and C10 tune the secondary of transformer T1. Two balanced anti-phase outputs, A and B, are available from T1; the secondary centre-tap is connected to the power return line.

Power supplies

5. The following power supplies are required:

(1)	+250V d.c., semi-regulated	-	350mA
(2)	-250V d.c., regulated	-	0·5mA
(3)	115V, 400c/s	-	negligible load
(4)	6·3V a.c. (earth level)	-	3·35A.

Voltage checks

6. Typical valve voltages are listed in Table 1 as an aid to fault finding. The voltages are measured with respect to "output zero power return", at PL1/10, using a multimeter.

TABLE 1

Typical valve voltages

Valve:	Pin No.:	Voltage measured:
V1 (6059)	3 (cathode)	+6·6V
V1, V2 (6059)	7 (anode)	+40V to +100V
	8 (screen)	+95V to +110V
V2 (6059)	3 (cathode)	+4·5V
V3, V4, V5, V6 (EL86)	3 (cathode)	+30V
	7 (anode)	+200V
	9 (screen)	+175V

Performance details

7. The performance of the 40V, 400c/s amplifier unit is as follows:

(1) Output amplitude stability - 400 ± 2c/s
(2) Output amplitude - - 35 to 55V r.m.s.
(3) Maximum undistorted output current - 50mA per phase.

Test procedure

8. The following items of test equipment are required when testing the 40V, 400c/s amplifier:

(1) Oscilloscope
(2) Valve voltmeter
(3) Two 5·6-kilohm, ±10 per cent, 1-watt resistors
(4) One 1-watt, 10-kilohm linear potentiometer.

Connect the required power supplies to the unit under test as detailed in para.5. Check, using the valve voltmeter, that the 115V reference supply is set to 115V r.m.s.

9. Connect one 5·6-kilohm resistor between PL1/3 and PL1/10; connect the second 5·6-kilohm resistor between PL1/10 and PL1/11. Connect the valve voltmeter and input A1 of the oscilloscope to PL1/11. Connect the signal earth return of the valve voltmeter and of the oscilloscope to PL1/10.

10. Switch on the power supplies and allow about 10 minutes for the unit to attain stable operating conditions.

11. Adjust potentiometer RV1 over its full range and check, using the valve voltmeter, that the output voltage varies from 35V to 55V r.m.s. Set RV1 to give an output voltage of 40V r.m.s. The output waveform, observed on the oscilloscope, must be devoid of noticeable distortion at all output levels.

12. Connect the ends of the 10-kilohm potentiometer to PL1/3 and PL1/11; connect the oscilloscope input to the potentiometer wiper and the oscilloscope earth return to PL1/10. Rotate the wiper of the 10-kilohm potentiometer until a minimum amplitude is observed on the oscilloscope. This minimum amplitude must not exceed 10mV peak-to-peak.

13. Disconnect the test equipment.

Chapter 6

DIGITAL BOARDS - INTRODUCTION

List of Contents

Introduction to digital-board descriptions

1. The digital boards used in the station selection digital system (Part 12, Chap.3) are described in Chap.6A to 6H inclusive. The boards contain various transistor circuit-elements (multivibrator, NAND-gates, OR-gates, monostable or bi-stable flip-flops, etc.) which provide the logical "bricks" that are used to form the digital circuits of the station selection digital system. In some instances, a digital circuit in the system is formed by utilizing one of each of a number of different boards; in other instances a number of boards of the same type are employed to provide a digital circuit.

2. The descriptions of the electronic operation of certain individual logical circuit-elements, are concerned with the response of the particular logical circuit when a negative or positive voltage is applied to the input, and also with the resultant negative or positive voltage at the output of the circuit. Normally, a negative voltage (-12V) condition is equivalent to the logical state '1' and the zero voltage (0V) condition is equivalent to the logical state '0'. To fulfil certain requirements of the digital system, however, a conversion from negative to positive logic is sometimes made. In these instances, a positive voltage (+12V) must be regarded as equivalent to logical '1' and zero voltage (0V) must still be regarded as equivalent to logical '0'. An explanation of these logical relationships is given in the description of the operation of the station selection digital system. The power supplies used throughout the digital system to provide the necessary biasing potentials to the semi-conductor transistors and diodes, are ±28V, ±12V and +6V.

Logical symbols

3. The individual circuit-elements on a particular board are symbolized by a logical symbol, as used in the logical diagrams which accompany the operational description of the station selection digital system. A logic diagram (sheet 2) is associated with each of the digital board circuit diagrams and uses the logical system-symbols to represent each circuit-element on the particular board. An explanatory diagram which defines these logical system-symbols is given in Part 6, Chap.1.

Digital-board tests

4. Operational tests of the digital boards are performed with the aid of the digital board test equipment (G.P.S. Part No. A98079/A). An individual board is plugged into the equipment, and a number of coding switches, test switches, output selection switches, metering and oscilloscope monitoring facilities are available on the front panel of the equipment. Correctly coded positive and negative input-voltages are selected and fed to the input-connections of the circuit-elements of any type of board by appropriate selection of the coding switches; the output of a particular circuit-element is loaded and monitored by the operation of the METER SELECTOR, LOAD SELECTOR and READ and LOAD switches to the appropriate positions.

5. The logical operation of the various transistor circuits may be determined by observation of the meter indication (+1, 0 or -1) which results from the application of the coded positive and negative input-voltages. Test procedures for individual boards include tables of coding switch positions which provide all the input-coding information to enable a particular type of board to be tested; a SIG GEN I/P terminal is provided for the connection of a pulse generator during certain tests. The power supply requirements for the test equipment are as follows:

(1) 240V, 50/60c/s - 1A
(2) +28V (stabilized) - 1A
(3) -28V (stabilized) - 1A.

6. The settings of the coding switches which are used on the test equipment, and the selected d.c. input-voltages or input-pulses associated with each code, are as follows:

(1) Code 1 - 0V
(2) Code 2 - -12V
(3) Code 3 - +12V
(4) Code 4 - Single shot positive-going pulse, controlled by the SINGLE SHOT switch
(5) Code 5 - -28V

(6) Code 6 - +28V
(7) Code 9 - Signal from an externally connected pulse generator.

7. Alternative procedures for testing the digital boards without the aid of the digital board test equipment can be performed provided that:

(1) The logical function of each circuit-element on a particular board is established (by reference to the appropriate circuit description).
(2) The input signals and power supplies of the correct polarity and amplitude are applied to the appropriate pin-connections on each board.
(3) The appropriate pin-connections to the outputs of each board are loaded and then monitored with the aid of the multimeter or oscilloscope to determine the correct output states for a given combination of input states.

Chapter 6A

CLOCK BOARD

List of Contents

List of Tables

List of Illustrations

Clock board

1. An introduction to the descriptions of the digital boards is given in Chap.6. The circuit diagram of the clock board is shown on sheet 1 of drawing C99092/01, the

logic diagram being shown on sheet 2. The following circuit-elements are mounted on the clock board:

(1) A master-clock pulse-generator (multivibrator), which is converted into a monostable circuit when one-shot operation of the clock-generation circuits is required (F1).
(2) A master-clock pulse-shaper circuit (A1).
(3) A master-clock high-power NAND stage with a "clock-gating" input which is not used in the station selection digital system (A2).
(4) A NAND-gate stage followed by two variable monostable circuits to provide delayed clock pulses (G1, F2 and F3). The gating input of the NAND-gate is not used in the station selection digital system.
(5) A separate pulse-shaper for the delayed clock pulses (A3).
(6) Two non-inverting, buffer amplifier stages with separate input and output connections; these circuits are used to amplify certain of the d.c. pulses in the station selection digital system, as required (A4 and A5).

Multivibrator clock-generator, pulse-shaper and power NAND-gate

2. When the coil of relay RL1 is de-energized, released contact sets RL1/1, /2, /3, /4, transistors VT1, VT2 and the associated components R1 to R4, C1 and C2, form a freely-running multivibrator circuit (F1, sheet 2). The output from VT1 collector is a square pulse of 20μs duration, rising from -12V to 0V, with an interval between pulses of 400μs. An external connection to the multivibrator output is provided by pin AD.

3. The multivibrator output is fed to the emitter-follower (common collector) buffer stage VT3, the emitter of which provides the input to the non-inverting pulse-shaping stages VT4 and VT5; these three stages (A1, sheet 2) are designed to improve the shape of the leading edge of the waveform. Resistors R8 and R12, which are connected to the base-inputs of VT4 and VT5 respectively, are shunted by "speed-up" capacitors C5 and C6. The capacitors compensate for the increased switching-times of VT4 and VT5 which occur at the higher input frequencies; these increases are caused by the effective input-capacitances of VT4 and VT5. The master-clock output from VT5 collector (R14) is available at pin M and is also connected, via MR2, as one input to the power NAND-gate (A2, sheet 2) circuit, formed by VT6, VT7 and associated components.

4. A "clock-pulse-gating" input to the power NAND-gate circuit, is provided by diode MR1. When the second input of the NAND-gate (pin V) is at a potential of 0V (logical '0'), diode MR1 conducts and the voltage at the junction of R15 and R16 is, therefore, 0V; this voltage causes VT6 to be biased to cut-off by the positive base-input voltage derived from the +6V supply, via the potential-divider resistors R17 and

Power supply requirements

12. The power supplies required for the clock board are as follows:

(1) -28V - 34mA (approximately)
(2) -12V - 82mA (approximately)
(3) +6V - 16mA (approximately).

Test procedure

13. The tests consist of checks of the amplitude and duration of the two-phase clock pulses, and tests of the logical operation of the NAND-gate circuit-elements and inverter amplifiers. The equipment required is as follows:

(1) Digital board test equipment (G.P.S. Part No. A98079/A)
(2) -28V, +28V and 240V, 50/60c/s supplies for the test equipment
(3) Multimeter
(4) Oscilloscope
(5) A pulse generator capable of supplying a +12V square-wave output at a frequency of 1kc/s.

14. Connect the power supplies (+28V, -28V and 240V, 50/60c/s) to the digital board test equipment (Part 5, Chap.6) and connect the multimeter and the oscilloscope inputs, in parallel, between the SCOPE O/P A and EARTH terminals on the test equipment front panel. Check the -12V and +12V supplies in the test equipment by switching on the AC and 28V switches and operating the METER SW switch to the -1 (-12V) and +1 (+12V) positions in turn; in each instance, the multimeter (d.c. range 25V) must indicate -12V and +12V, respectively, when the READ switch is operated. If necessary, adjust the appropriate -12V or +12V control on the test equipment power supplies to obtain the correct reading on the multimeter; disconnect the multimeter from the SCOPE O/P A terminal and check that the voltage between pins AJ of SKT1 and SKT2 is between +5·8V and +6·5V with respect to the EARTH terminal. Switch off the test equipment, disconnect the multimeter and plug the clock-board into SKT1 or SKT2.

Amplifiers A4, A5 and clock-pulse generation tests

15. Set the coding switches to the positions shown in Table 1, switch on the test equipment and, selecting the coding switches as required, carry out the tests of the clock-board circuit-elements according to the instructions given in (1) to (15) inclusive.

TABLE 1

Coding switch positions - A4, A5, A1, A2, G1, F2, A3, F5

Coding switches:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0

(1) Set the SCOPE AND METER SELECTOR switch to C, the METER SW to -1, operate the READ switch and check that the meter M1 indicates -1 (component tested, A4).

(2) Set the SCOPE AND METER SELECTOR to E, operate the READ switch and check that M1 indicates -1 (component tested, A5).

(3) Set the SCOPE AND METER SELECTOR to M and check that the oscilloscope displays positive-going pulses with an amplitude of +12V with respect to 0V. Check that the pulse-duration is 20μs with 400μs between positive-going edges (component tested, A1).

(4) With the SCOPE AND METER SELECTOR set to N, and the LOAD SELECTOR set to -16, operate the LOAD switch and check that the oscilloscope displays negative-going pulses of -12V amplitude with respect to 0V. Check that the pulse-duration is 20μs with 400μs between negative-going edges (component tested, A2).

(5) With the SCOPE AND METER SELECTOR set to P, check that the oscilloscope displays the same waveform as that in (4) above, except that the rise-time of the positive-going edge is slightly greater (component tested, G1).

(6) With the SCOPE AND METER SELECTOR set to R, check that the oscilloscope displays negative-going pulses with an amplitude of -12V with respect to 0V. Check that the pulse-duration is 300μs (component tested, F2).

(7) Set the SCOPE AND METER SELECTOR switch to S and the LOAD SELECTOR to -16; operate the LOAD switch and check that the oscilloscope displays negative-going pulses with an amplitude of -12V and a duration of 50μs (component tested, A3).

(8) Set the SCOPE AND METER SELECTOR switch to T and with the LOAD switch unoperated, check that the oscilloscope displays a waveform similar to that in (7) above (component tested, F3).

(9) Switch off the test equipment and set the coding switches to the positions shown in Table 2.

TABLE 2

Coding switch positions - A4, A5

Coding switches:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(10) Switch on the test equipment and with the SCOPE AND METER SELECTOR switch set to C, the METER SW at 0 and the LOAD SELECTOR at -1, operate the READ switch and check that meter M1, indicates 0. Operate the READ and LOAD switches together and check that the M1 indication remains at 0.
(11) Set the SCOPE AND METER SELECTOR switch to E, operate the READ and LOAD switches and check that meter M1 indicates 0.
(12) Switch off the test equipment and set the coding switches to the positions shown in Table 3.

TABLE 3

Coding switch positions - A2, G1 to A3

Coding switches:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

(13) Switch on the test equipment and with the SCOPE AND METER SELECTOR switch set to N and the METER SW at -1, operate the READ switch and check that meter M1 indicates -1 (component tested, A2).
(14) Set the SCOPE AND METER SELECTOR switch to S, the LOAD SELECTOR to -16 and check that the oscilloscope displays negative-going pulses with an amplitude of -12V with respect to 0V. Check that the pulse-duration is 50μs (component tested, A3). Switch off the test equipment and set the coding switches to the positions shown in Table 4.

TABLE 4

Coding switch positions - G1

Coding switches:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

(15) With the SCOPE and METER SELECTOR switch set to R and the METER SWITCH at 0, operate the READ switch and check that meter M1 indicates 0. Switch off the test equipment.

One-shot clock-pulse tests

16. Set the coding switches to the positions shown in Table 5 and carry out the tests given in sub-para. (1) to (5) inclusive.

TABLE 5

Coding switch positions - F1, one-shot

Coding switches:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	6	0	0	0	0	0

(1) Connect the pulse generator to the SIG GEN I/P terminals A and EARTH. Adjust the pulse generator to provide a positive-going 1kc/s square-wave output with an amplitude of +12V (1ms between positive going edges). Check the pulse generator output by setting the SCOPE AND METER SELECTOR to W and observing the 1kc/s square-wave on the oscilloscope.
(2) Set the SCOPE AND METER SELECTOR switch to N, the LOAD SELECTOR to -16, operate the LOAD switch and check that the oscilloscope displays negative-going pulses of -12V amplitude with respect to 0V. Check that the pulse-duration is 20μs with 980μs between the negative-going edges.
(3) Set the SCOPE AND METER SELECTOR switch to R and check that the oscilloscope displays negative-going pulses of -12V amplitude with respect to 0V. Check that the pulse-duration is 300μs with 960μs between negative-going edges.
(4) Set the SCOPE AND METER SELECTOR switch to S, the LOAD SELECTOR to -16 and check that the oscilloscope displays negative-going pulses with an amplitude of -12V with respect to 0V and with a pulse-duration of 50μs.
(5) Switch off the test equipment and remove the clock board.

Chapter 6B

GENERAL NAND BOARD

List of Contents

List of Tables

List of Illustrations

General NAND board

1. An introduction to the descriptions of the digital boards is given in Chap.6. The circuit diagram of the general NAND board is shown on sheet 1 of drawing C99086/01; the logic diagram is shown on sheet 2 of the same drawing. Twelve inverter amplifier circuit-elements are mounted on the board. A zero potential (logical '0') applied to the input of each circuit results in a negative voltage (logical '1') at the output. A single diode provides the input to eight of the inverter amplifiers (G1 to G8, sheet 2); the input signal to the other four inverter amplifiers (G9 to G12, sheet 2) is applied directly to the base-input resistor of the first stage. Except for the omission of the input-diode on four of the circuit-elements (G9 to G12), all twelve NAND circuit-

elements are identical. A circuit description is given of one inverter-amplifier with a single diode input (G1, sheet 2).

Inverter amplifier circuit description

2. Resistors R3, R4, diode MR1 and resistor R1 are connected as a potential divider network between the -28V supply line and the +6V supply line. With a negative voltage (logical '1') applied to the anode of the input diode MR2 (pin AC), the diode is non-conductive, and the negative potential at the junction of negative-bias resistor R3 and the base-input resistor R4 causes the base-input-switching diode MR1 to conduct; the resulting negative potential at the base of VT1 switches the transistor into conduction. The output-potential from VT1 collector (pin AD) is therefore zero (logical '0'). When 0V (logical '0') is applied to the anode of the input diode MR2, the diode conducts and the potential at the junction of R3 and R4 rises to 0V. Transistor VT1 is cut off by the resulting positive base-biasing potential derived from the +6V supply line via the divider network consisting of R1, MR1 and R4. The potential at the collector of the grounded-emitter stage VT1 then reaches approximately -12V (logical '1').

3. The switching-action of diode MR1 ensures that VT1 cuts off sharply when the positive-going edge of the input waveform is applied to the anode of the input-diode MR2. Similarly, when the negative-going edge of the input waveform is applied to MR2, the switching-action of this input-diode ensures a sharp rise in the negative transistor-switching voltage at the junction of R3 and R4.

4. The operation of the four inverter amplifiers which have no diode connected to their inputs (G9 to G12, sheet 2), is similar to that of the NAND circuit-element inverter amplifier described in para. 2 and 3; each of these four circuit-elements functions as a simple buffer amplifier inverting stage.

Power supply requirements

5. The power supplies required for the general NAND board are approximately as follows:

(1) -28V - 250mA
(2) -12V - 30mA
(3) +6V - 34mA.

Test procedure

6. The test procedure consists of checks of the operation of each of the general

NAND circuit-elements on the board by the application of coded negative and positive input voltages, and observation of the resultant d.c. output voltage on the meter on the front panel of the test equipment. The following equipment is required:

(1) Digital board test equipment (G.P.S. Part No. A98079/A)
(2) -28V, +28V and 240V, 50/60c/s supplies for the test equipment
(3) Multimeter.

All the controls mentioned in the test procedure instructions are situated on the test equipment unit.

7. Connect the power supplies (+28V, -28V and 240V 50/60c/s) to the digital board test equipment and connect the multimeter between the SCOPE O/P A and EARTH terminals on the test equipment panel. Check the -12V and +12V supplies in the test equipment by switching on the AC and 28V switches. Operate the METER SW switch, to the -1 (-12V) and +1 (+12V) positions, in turn; in each instance the multimeter (d.c. range 25V) must indicate -12V and +12V respectively when the READ switch is operated. If necessary, adjust the appropriate -12V or +12V control, in the power circuits within the test equipment unit, to obtain the correct reading on the multimeter; disconnect the multimeter from the SCOPE O/P A terminal and check that the voltage between pins AJ of SKT1 and SKT2 is +5·8V to +6·5V with respect to the EARTH terminal. Switch off the test equipment, disconnect the multimeter and plug the general NAND board into SKT1 or SKT2.

General NAND circuit-elements G1 to G12

8. Set the coding switches to the positions shown in Table 1, switch on the test equipment and, operating the coding switches as required, carry out the tests according to the instructions in sub-para. (1) to (4) inclusive.

TABLE 1

Coding switch positions A - G1 to G12

Coding switches:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	6	0	6	0	6	0	6	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

(1) Set the METER SW to -1 and then set the SCOPE AND METER SELECTOR switch, in turn, to positions D, F, J, L, N, R, T, V, X, Z, AB and AD. For each of the selected positions of the SCOPE AND METER SELECTOR switch, operate the READ switch and check that, in each case, the meter M1 indicates -1

(2) Switch off the test equipment and set the coding switches to the positions shown in Table 2.

TABLE 2

Coding switch positions B - G1 to G12

Coding switches:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	0	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0

(3) Switch on the test equipment and with the LOAD SELECTOR set to -5 and the METER SW set to 0, set the SCOPE AND METER SELECTOR switch, in turn, to positions D, F, J, L, N, R, T, V, X, Z, AB and AD. For each of the selected positions of the SCOPE AND METER SELECTOR switch, operate the READ switch; check, in each case, that meter M1 indicates 0, and then operate the READ and LOAD switches together and check that in each case, the M1 indication remains at 0.

(4) Switch off the test equipment and remove the general NAND board.

Chapter 6C

HIGH-POWER NAND BOARD

List of Contents

List of Tables

List of Illustrations

High-power NAND board

1. The circuit diagram of the high-power NAND board is shown on sheet 1 of drawing C99098/01; the logic diagram is shown on sheet 2. Six NAND circuit-elements are mounted on the board. Four circuit-elements (G1 to G4, sheet 2) are identical except for component references; two circuit-elements (G5 and G6, sheet 2) are similar to the other four, except that their output stages are supplied from -28V instead of -12V. Each circuit-element consists of a two-stage inverter amplifier with a single-diode input. The emitter of the first (emitter-follower) stage provides the

input to the second (grounded emitter) stage. The power output from this second stage supplies power to certain externally-connected digital circuits; e.g., the 'set' and 'reset' busbars of the receiver systems in the station selection digital system (Part 12, Chap.3). The circuit description is applicable to the high-power NAND circuit-element (G1, sheet 2).

High-power inverter amplifier description

2. Transistors VT1 and VT2 together with the associated components (sheet 1), form the two-stage inverter amplifier circuit (G1, sheet 2). With a negative voltage (logical '1') connected to the anode of the input diode MR2 (pin AD, sheet 1), this diode is rendered non-conducting. The negative base-bias potential to VT1 is fed from the junction of diode MR1 and resistor R4, and is determined by a divider-network connected between the -28V and +6V supply lines; the network consists of resistors R1, R3, R4 and the forward-biased, base-input-switching diode, MR1. The emitter of VT1 is returned to the +6V supply, via R5, and the resultant base-emitter potential switches VT1 into conduction. The negative voltage at the emitter of VT1 then switches the grounded-emitter stage VT2 into conduction: the output voltage at the collector (R6) of VT2 is, therefore, 0V (logical '0').

3. When VT1 and VT2 are conducting heavily, the potential at the emitter of VT1 is approximately at earth potential. The collector of VT1 is fed from the -28V supply line via the limiting resistor R2, and to overcome any variation in transistor characteristics which may result in the transistor "bottoming", the collector voltage is limited by MR3, the cathode of which is connected to earth; the collector-potential of VT1 can never, therefore, rise above earth potential (0V).

4. If zero potential (logical '0') is applied to the anode of the input diode MR2, the diode conducts and VT1 is cut off by the positive base-input potential derived from the +6V supply line, via resistor R4. The resultant positive potential across the emitter load-resistor (R5) of VT1, cuts off VT2, and the output voltage from VT2 collector (pin AC) is, therefore, negative (logical '1').

Power supply requirements

5. The power supplies required for the high-power NAND board are, approximately, as follows:

(1)	-28V	-	270mA
(2)	-12V	-	30mA
(3)	+ 6V	-	35mA.

Test procedure

6. The test procedure consists of checks of the logical operation of each of the high-power NAND circuit-elements by the application of coded positive and negative input-voltages, and by observation of the resultant d.c. output voltages, indicated on the meter (M1) and the LEVEL INDICATOR, which are both located on the front panel of the digital board test equipment. The following test equipment is required:

(1) Digital board test equipment (G.P.S. Part No. A98079/A)
(2) -28V, +28V and 240V, 50/60 c/s supplies for the test equipment
(3) Multimeter.

All the controls mentioned in the test procedure instructions are situated on the test equipment unit.

7. Connect the power supplies (+28V, -28V and 240V, 50/60 c/s) to the digital board test equipment, and connect the multimeter between the SCOPE O/P A and EARTH terminals on the test equipment front panel. Switch on the test equipment by means of the AC and 28V switches. Check the -12V and +12V supplies by operating the METER SW switch, sequentially, to the -1 (-12V) and +1 (+12V) positions; the multimeter (d.c. range 25V) must indicate -12V and +12V, respectively, when the READ switch is operated. If necessary, adjust the appropriate -12V or +12V control, in the power circuits within the test equipment unit, to obtain the correct reading on the multimeter; disconnect the multimeter from the SCOPE O/P A terminal and check that the voltage between pin AJ of SKT1 and SKT2 is between the limits +5·8V to +6·5V. Switch off the test equipment, disconnect the multimeter and plug the high-power NAND board into SKT1 or SKT2.

High-power NAND circuit-elements G1 to G6

8. Set the coding switches initially to the positions shown in Table 1, switch on the test equipment and implement the tests according to the instructions in sub-para. (1) to (3) inclusive.

TABLE 1

Coding switch positions A - G1 to G6

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	2	0	2	0	2	0	2

(1) With the METER SW switch set to 0 and the LOAD SELECTOR switch set to -100, set the SCOPE AND METER SELECTOR, sequentially, to the following positions: S, U, W, Y, AA and AC. For each position of the SCOPE AND

METER SELECTOR switch, operate the READ and LEVEL INDICATOR switches and check that:

(a) meter M1 indicates 0
(b) the LEVEL INDICATOR lamp, on the test equipment front panel, lights.

The components tested when the SCOPE AND METER SELECTOR is selected to each of the six positions, are G6, G5, G4, G3, G2 and G1, respectively.
(2) Switch off the test equipment and set the coding switches to the positions shown in Table 2.

TABLE 2

Coding switch positions B - G1 to G6

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1

(3) Switch on the test equipment and set the SCOPE AND METER SELECTOR switch to the following positions, sequentially: S, U, W, Y, AA and AC. For each position of the SCOPE AND METER SELECTOR switch, operate the LEVEL INDICATOR switch and check that the LEVEL INDICATOR lamp on the test equipment front panel is extinguished. The components tested, when the SCOPE AND METER SELECTOR is set to each of the six positions, are G6, G5, G4, G3, G2 and G1, respectively.
(4) Switch off the test equipment and remove the high-power NAND board.

Chapter 6D

STATICISER BOARD

List of Contents

List of Tables

List of Illustrations

Staticiser board - type 2

1. An introduction to the descriptions of the digital boards is given in Chap.6. The circuit diagram of the staticiser board, type 2, is shown on sheet 1 of drawing C208472/01; the logic diagram is shown on sheet 2.

2. Eight identical transistor bi-stable flip-flop circuits (F1 to F8, sheet 2) are mounted on staticiser board, type 2. Four of these bi-stable circuits share a common trigger-pulse input (pin AH); the other four bi-stables share a second common trigger-pulse input (pin B). The load of one collector of each pair of

transistors in an individual bi-stable circuit consists of a relay coil; the coil is external to the staticiser board. Each bi-stable and its associated relay coil form a "staticiser", i.e., a binary "one-bit" store.

3. The binary states, represented by positive and negative voltages, that are to be stored by each staticiser, are fed to two "set" and "reset" diodes in the bi-stable input-circuits. When the trigger-pulse is applied to the appropriate trigger-pulse input-line (pin AH or pin B), each of the four bi-stables that share this common trigger-input, assumes a binary state that is determined by the binary states existing at their "set" and "reset" diode inputs. The relay coil associated with each bi-stable is energized or de-energized depending on the binary state of the bi-stable. The operation of one bi-stable staticiser circuit (F1, sheet 2) is described.

Bi-stable circuit description

4. Transistors VT1 and VT2 (sheet 1) together with the associated components, form a conventional Eccles-Jordan bi-stable circuit. The two circuit-states are as follows:

(1) VT1 conducting heavily and VT2 cut-off. The collector of VT1 is connected to the -28V supply line of the digital system, via pin AC, a staticiser relay coil and a switch; both of these components are external to the digital board. The relay is energized when the bi-stable is in this (set) state.
(2) VT1 cut-off and VT2 conducting; the relay coil is de-energized in this (reset) state.

A cumulative transistor switching-action is achieved by resistors R9 and R3 which couple VT1 collector to VT2 base, and VT2 collector to VT1 base, respectively.

5. A negative-going trigger-pulse of -12V amplitude and 20μs duration is required to trigger the bi-stable. When a trigger-pulse is not applied, the potential of the pulse line (pin AH) is 0V; this causes both trigger-diodes MR1 and MR6 to conduct, and the normal potential at the junctions of resistors R1, R4, and R8, R7 respectively, in the absence of a trigger-pulse, is, therefore, 0V. The description of the bi-stable circuit operation is based on the following circuit states:

(1) The potential on the anode of the "set" diode MR2 (pin AD) is negative (logical '1'); the diode is, therefore, non-conducting. The potential on the anode of the "reset" diode MR5 (pin AB) is 0V (logical '0'); MR5 is, therefore, conducting.
(2) The bi-stable circuit is in the reset state (VT1 cut-off and VT2 conducting).

6. The application of the trigger-pulse (-12V) to pin AB renders MR1 and MR6 non-conducting for 20μs and results in a negative potential at the junction of negative-bias resistor R1 and base-input resistor R4; this potential persists for the duration of the trigger-pulse.

7. The base-input-switching diode MR3 now conducts, via resistor R4, and the negative voltage is applied to the base of VT1 which conducts heavily. Resistors R6 and R9 are connected in a divider-network to the +6V supply line, and the potential existing at VT1 collector approximates to "earth" (0V) potential; this condition results in VT2 being cut off by the positive potential which is derived from the junction of R6 and R9. The bi-stable circuit is now in the set state. When the input-voltages to the "set" and "reset" diodes are as stated in para. 5(1) and the trigger-pulse is applied to the bi-stable, diode MR6 is rendered non-conducting but, due to the conduction of MR5, the potential at the junction of R8 and R7 remains 0V (logical '0').

8. Reversal of the input-voltages to the "set" and "reset" diodes (MR2 and MR5), followed by the application of a second trigger-pulse to the anodes of MR1 and MR6 (pin AH), results in a negative potential at the junction of R8 and R7 which switches VT2 into conduction, and resets the bi-stable.

Power supply requirements

9. The power supplies required for the staticiser board are, approximately, as follows:

(1) -28V - 50mA
(2) + 6V - 2mA.

Test procedure

10. The test procedure consists of checks of the flip-flop operation by applying coded positive and negative input voltages to the "set" and "reset" input-diodes of each bi-stable flip-flop with a standing potential of -12V applied to the trigger-pulse lines (pins B and AH). The state of each bi-stable is then checked by observing the indication on meter M1 and/or the LEVEL INDICATOR lamp on the front panel of the digital board test equipment. The following equipment is required:

(1) Digital board test equipment (G.P.S. Part No. A98079/A)
(2) -28V, +28V and 240V, 50/60c/s supplies for the test equipment
(3) Multimeter.

All the controls mentioned in the test procedure instructions are situated on the test equipment unit.

11. Connect the power supplies (+28V, -28V and 240V, 50/60c/s) to the digital board test equipment and connect the multimeter between the SCOPE O/P A and EARTH terminals on the test equipment front panel. Switch on the test equipment by means of the AC and +28V switches. Check the -12V and +12V supplies by operating the METER SW switch to the -1 (-12V) and +1 (+12V) positions, in turn; the multimeter (d.c. range 25V) must indicate -12V and +12V, respectively, when the READ switch is operated. If necessary, adjust the appropriate -12V or +12V control in the power circuits within the test equipment unit to obtain the required reading on the multimeter; disconnect the multimeter from the SCOPE O/P A terminal and check that the voltage between pins AJ of SKT1 and SKT2 is between the limits +5·8V to 6·5V. Switch off the test equipment, disconnect the multimeter, link pins AH and B on the staticiser board type 2, and plug the board into SKT1 or SKT2.

12. Set the coding switches to the positions shown in Table 1, switch on the test equipment and conduct the tests according to the instructions in sub-para. (1) to (3) inclusive.

TABLE 1

Coding switch positions A - F1 to F8

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	2	1	5	2	1	5	2	1	5	2	1	5	2	1	5	2	1	5	2	1	5	2	1	5	2

(1) With the METER SW set to 0, set the SCOPE AND METER SELECTOR switch, sequentially, to positions D, H, L, P, T, W, Z, AC. For each position of the SCOPE AND METER SELECTOR switch, operate the READ and LEVEL INDICATOR switches and check that:

(a) meter M1 indicates 0
(b) the LEVEL INDICATOR lamp, on the test equipment front panel, lights.

The components tested, when the SCOPE AND METER SELECTOR is selected to each of the eight positions, are F8, F7, F6, F5, F4, F3, F2 and F1, respectively.

(2) Switch off the test equipment and set the coding switches to the positions shown in Table 2.

TABLE 2

Coding switch positions B - F1 to F8

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	2	2	5	1	2	5	1	2	5	1	2	5	1	2	5	1	2	5	1	2	5	1	2	5	1

(3) Switch on the test equipment and set the SCOPE AND METER SELECTOR switch, sequentially, to positions: D, H, L, P, T, W, Z and AC. For each position of the SCOPE AND METER SELECTOR, operate the LEVEL INDICATOR switch and check that the LEVEL INDICATOR lamp on the front panel is extinguished. The components tested when the SCOPE AND METER SELECTOR is set to each of the eight positions, are F8, F7, F6, F5, F4, F3, F2 and F1, respectively.

(4) Switch off the test equipment and remove the staticiser board.

Chapter 6E

STATION BOARD

List of Contents

List of Tables

List of Illustrations

Station board

1. An introduction to the description of the digital boards is given in Chap.6. The circuit diagram of the station board, type 2, is shown on sheets 1 and 2 of drawing C99087/01; the logic diagram is shown on sheet 3.

2. Two bi-stable flip-flop circuits, together with NAND circuit-elements, delay circuit-elements and inverter amplifiers, each of which is associated with each of the bi-stables, are mounted on the station board. Each bi-stable is designed to provide one stage of a "station" ring-counter which forms part of the station selection digital system (Part 12, Chap.3). The inputs and outputs of each of the circuit-elements and, therefore, the logical conditions that control their operation, are related to the function of the circuit-elements when forming part of a ring-counter stage.

3. Transistors VT2 and VT3 (sheet 1) together with the associated components form an Eccles-Jordan bi-stable flip-flop circuit (F1, sheet 3). The logical circuit-elements associated with this bi-stable circuit are as follows:

(1) General NAND circuit-elements (G1 and G2, sheet 3)
(2) Two delay elements (A2 and A3, sheet 3)
(3) Two inverter amplifiers (A1 and A7, sheet 3)
(4) Two diodes (MR5 and MR6, sheets 1 and 3) which provide an extra facility for resetting the bi-stable circuit, and a method of "sampling" the set or reset state of the bi-stable (para. 17).

4. The bi-stable 'set' and 'reset' inputs (pins Y and AA, respectively) are provided by the delayed 'set' and 'reset' outputs of the preceding bi-stable in the ring-counter. Both the 'set' and 'reset' bi-stable outputs are fed, via the delay elements A2 and A3 (sheet 3), to pins X and V, respectively; the bi-stable outputs are also fed directly to pins Z and W, respectively. The 'reset' outputs are fed, via two inverting amplifiers (A1 and A7) to pins U and T, respectively. The general NAND circuit-element G1 provides inversion and amplification of the bi-stable trigger-pulse input-signal (pin AC); the general NAND circuit-element G2 provides inversion and amplification of the output of circuit-element A1. The delayed outputs of the bi-stable are normally fed to the inputs of the succeeding bi-stable in the ring-counter.

Station board circuit description

5. The two states of the bi-stable circuit, formed by VT2 and VT3 (sheet 1) and associated components, are as follows:

(1) VT2 conducting heavily and VT3 cut-off (reset)
(2) VT3 conducting heavily and VT2 cut-off (set).

The cumulative switching-action of the conventional Eccles-Jordan bi-stable circuit is achieved by resistors R11 and R8 which couple VT2 collector to VT3 base (via MR10) and VT3 collector to VT2 base (via MR8), respectively.

Bi-stable trigger-pulse

6. A trigger-pulse (clock-pulse) rising from -12V to 0V is fed from the clock-generator to the NAND circuit-element (G1, sheet 3). In the absence of a trigger-pulse, the trigger-pulse line (pin AC, sheet 1) is at a potential of 0V, and MR1 is, therefore, conducting. The resultant potential (0V) at the junction of R1 and R2 ensures that VT1 is cut off by the positive potential derived from the divider-network R4, MR2 and R2. The potential at the collector of VT1 is, therefore, at -12V (logical '1'). The application of the negative-going trigger-pulse to the trigger-pulse line renders diode MR1 non-conducting for 20μs (trigger-pulse duration). The resultant negative potential at the junction of R1 and R2 causes VT1 to conduct and the positive-going edge of the waveform at VT1 collector provides the trigger-pulse, via C2, MR4 and C4, MR11, to the base-circuits of the bi-stable transistors, VT2 and VT3.

Bi-stable operation

7. The normal set and reset inputs to the bi-stable circuit are provided by diodes MR12 and MR3 which are connected to pins Y and AA, respectively. Given that the following bi-stable circuit and set/reset diode-input states exist:

(1) VT2 conducting and VT3 cut-off (bi-stable circuit in the reset state)
(2) The 'set' input to the anode of diode MR12 (pin Y) is -12V (logical '1'); this diode is, therefore, cut off
(3) The 'reset' input to the anode of diode MR3 (pin AA) is 0V (logical '0'); this diode is, therefore, conducting
(4) The potential of the trigger-pulse line (pin AC) is 0V (i.e., trigger-pulse not applied),

the ensuing operation of the bi-stable will be as described in para.8 to 12 inclusive.

8. When the trigger-pulse (-12V) is applied to pin AC a positive-going pulse-edge, is applied, via C2, to the anode of diode MR4 which conducts and causes VT2 to cut-off. The resultant negative voltage of VT2 collector is fed, via R11 and MR10, to the base of VT3 and switches this transistor into conduction. The bi-stable circuit is now in the set state.

9. Reversal of the 'set' and 'reset' inputs and the application of a second trigger-pulse, results in the bi-stable circuit assuming its original (reset) state. Thus, for the bi-stable to change state when the trigger-pulse is applied, the set and reset inputs must have opposite logic states to the set and reset outputs.

10. The collectors of VT2 and VT3 are supplied with -28V, via R63 and R7, and R65 and R10; the 'clipping' diodes MR14 and MR21, limit the collector-voltages of VT2 and VT3 to -12V when the transistors are cut off, thus improving the rise-times of the negative-going edges of the waveform at each collector.

11. Base-input-switching diodes MR8 and MR10, the anodes of which are fed from the +6V supply line via resistors R9 and R12, improve the switching-time of the bi-stable circuit and prevent any excessive variation in trigger-pulse sensitivity which might otherwise occur as the result of variation in transistor characteristics.

12. When VT2 and VT3 are conducting heavily, their collector voltages are limited to their base potentials by the 'collector-catching' diodes MR7 and MR9. The transistors are not, therefore, allowed to "bottom".

Bi-stable delayed outputs

13. The collector-output of VT2 in the bi-stable circuit, is fed to a delay circuit-element formed by VT4, C5, R15 and R16. A pulse delay-time of 55μs is introduced by the integrating circuit consisting of R15 and C5, and the delayed output pulse is fed to pin X from the load-resistor of the emitter-follower (common collector) stage, VT4. The input of a similar delay circuit (VT3, C6, R17 and R18) is fed with the bi-stable output from the collector of VT3.

Inverted bi-stable outputs

14. The output from the collector of VT3 is fed, via the input-switching diode MR15, to a two-stage inverter amplifier (A7, sheet 3) consisting of VT6, VT19 and the associated components. The base-switching voltage to VT6, which is an emitter-follower stage, is determined by the potential-divider network R19, R20 and R22. A negative voltage (logical '1') applied (from VT3 collector) to the anode of diode MR13 results in a negative potential at the junction of R19 and R20; this potential causes VT6 to conduct. The resultant negative potential at VT6 emitter, switches VT19 into conduction. Thus, the collector of this second stage (grounded emitter) provides an output of zero volts (logical '0') at its collector. A two-stage inverter and power-amplifier circuit (A1, sheet 2) is formed by VT7, VT8 and the associated components; the input stage (VT7) of this inverter is fed from VT3 collector, via MR15. The output from the collector of the inverter power stage (VT8) is fed to pin U and provides the switching potentials for the station selection frequency busbars (Part 12, Chap.3).

15. When the potential at the collector of VT3 is negative (bi-stable reset), MR15 is rendered non-conducting and the resulting negative potential at the junction of R23 and R24, fed via the base-input-switching diode MR16, causes the emitter-follower input-stage, VT7, to conduct. To compensate for any variation in transistor

characteristics and to prevent VT7 from "bottoming", MR17 limits the collector-potential of VT7 to earth potential. The collector of VT8 is normally supplied (via pin U) from a load resistor which is external to the digital board and which is connected to -28V; the negative potential at the emitter of VT7 (R26) causes VT8 to conduct and the output at pin U is therefore 0V (logical '0'). When VT8 is not conducting, its collector potential is limited to -12V by MR18.

General NAND circuit-element

16. A general NAND circuit-element (G2, sheet 3) is formed by VT9, MR19, MR20 (sheet 1) and the associated resistors, and provides inversion and amplification of A1 output. The operation of the circuit is similar to the operation of the general NAND circuit-elements described in Chap.6B.

Diodes MR5 and MR6

17. Diode MR5 (sheet 1) provides a "resetting" input to the bi-stable flip-flop. When a potential of 0V (logical '0') is applied to the anode of MR5, the diode conducts and the potential at the collector of VT2 is 0V; the bi-stable flip-flop then assumes the reset state. Diode MR6 is used as part of a multiple-input OR-gate which is connected to the station ring-counter. This OR-gate is designed to "sample" the state of the bi-stable flip-flop for ring-counter resetting purposes (Part 12, Chap.3).

Power supply requirements

18. The power supplies required for the station board are approximately, as follows:

(1) -28V - 425mA
(2) -12V - 320mA
(3) + 6V - 12mA.

Test procedure

19. The test procedure consists of checks of the operation of each bi-stable flip-flop and its associated delay circuit-elements, NAND gating elements and inverter amplifiers. These tests are implemented by first applying the coded positive and negative input-voltages and then setting or resetting the bi-stable flip-flop by a SINGLE SHOT trigger-pulse from the digital board test equipment. The resultant d.c. output voltages are then indicated by meter M1 on the test equipment front panel. The following test equipment is required:

(1) Digital board test equipment (G.P.S. Part No. A98079/A)
(2) -28V, +28V and 240V, 50/60c/s supplies for the test equipment
(3) Multimeter.

All the controls mentioned in the test procedure instructions are situated on the test equipment unit.

20. Connect the power supplies (-28V, +28V and 240V, 50/60c/s) to the digital board test equipment and connect the multimeter between the SCOPE O/P A and EARTH terminals on the test equipment panel. Switch on the test equipment by means of the AC and 28V switches. Check the -12V and +12V supplies by operating the METER SW switch to the -1 (-12V) and +1 (+12V) positions in turn. Check that the multimeter (d.c. range 25V) indicates -12V and +12V, respectively. If necessary, adjust the appropriate -12V or +12V control, in the power circuits within the test equipment unit, to obtain the correct indications on the multimeter; disconnect the multimeter from the SCOPE O/P A terminal and check that the voltage between pins AJ or SKT 1 and SKT 2 is within the limits +5·8V to +6·5V measured with respect to the EARTH terminal. Switch off the test equipment, disconnect the multimeter and plug the station board into SKT 1 or SKT 2.

21. Set the coding switches to the positions shown in Table 1. Switch on the test equipment and operate the SINGLE SHOT switch. Carry out the tests according to the instructions given in sub-para. (1) to (3) inclusive.

Note...

It is important to maintain the correct sequence when setting the coding switches, switching on and operating the SINGLE SHOT switch. The test equipment must not be switched off, nor must the board be removed from the test equipment, before the completion of all tests.

TABLE 1

Coding switch positions A - FF1, FF2, G1 to G6, A1 to A6

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	2	0	0	0	1	4	0	0	0	0	0	0	2	0	1	0	4	0

(1) Set the SCOPE AND METER SELECTOR switch, in turn, to the positions shown in column 1 of Table 2, the METER SW to the positions shown in column 2 and the LOAD SELECTOR to the positions shown in column 3. Operate the READ switch as instructed in column 4 (test A) and observe that, in each instance, meter M1 indication is as shown in column 2 (0 or -1). Where the READ and LOAD instructions in column 5 (test B) are indicated, these operations must be performed in addition to the instructions in column 4, and the meter M1 indication must, in each instance, remain as shown in column 2.

Note...
In the SCOPE AND METER SELECTOR positions H and U, the instructions to LOAD and READ (test A) indicate that both the LOAD and READ switches must be operated together.

TABLE 2

Test equipment switch positions A

SCOPE AND METER SELECTOR:	METER SW and M1 indication:	LOAD SELECTOR:	Test A READ:	Test B READ and LOAD:	Component tested:
B	0	-	READ	-	FF2
D	-1	-	READ	-	A5
E	0	-1	READ	READ and LOAD	A6
F	-1	-16	READ	READ and LOAD	G6
H	-1	-100	LOAD and READ	-	A4
J	0	-5	READ	READ and LOAD	G5
L	-1	-	READ	-	FF2
M	-1	-	READ	-	FF2
N	-1	-	READ	-	FF2
S	0	-5	READ	READ and LOAD	G2
T	-1	-	READ	-	G3
U	-1	-100	LOAD and READ	-	A1
V	0	-1	READ	READ and LOAD	A3
W	0	-	READ	-	FF1
X	-1	-	READ	-	A2
Z	-1	-	READ	-	FF1
AB	-1	-	READ	-	FF1
AD	-1	-	READ	-	FF1

(2) Set the coding switches to the positions shown in Table 3 and operate the SINGLE SHOT switch.

TABLE 3

Coding switch positions B - FF1, FF2, G1 to G6, A1 to A6

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	1	0	0	0	2	4	0	0	0	0	0	0	1	0	2	0	4	0

(3) Carry out the test instructions given in (1) above but in this instance, use the test equipment switch positions given in Table 4.

TABLE 4

Test equipment switch positions B

SCOPE AND METER SELECTOR:	METER SW and M1 indication:	LOAD SELECTOR:	Test A READ:	Test B READ and LOAD:	Component tested:
B	-1	-	READ	-	FF2
D	0	-1	READ	READ and LOAD	A5
E	-1	-	READ	-	A6
F	0	-16	READ	READ and LOAD	G6
H	0	-100	LOAD and READ	-	A4
J	-1	-	READ	-	A5
L	0	-	READ	-	FF2
M	0	-	READ	-	FF2
N	0	-	READ	-	FF2
S	-1	-	READ	-	G2
T	0	-16	READ	READ and LOAD	G3
U	0	-100	LOAD and READ	-	A1
V	-1	-	READ	-	A3
W	-1	-	READ	-	FF1
X	0	-1	READ	READ and LOAD	A2
Z	0	-	READ	-	FF1
AB	0	-	READ	-	FF1
AD	0	-	READ	-	FF1

(4) Switch off the test equipment and disconnect the station board.

Chapter 6F

RECEIVER BOARD

List of Contents

List of Tables

List of Illustrations

Receiver board

1. An introduction to the descriptions of the digital boards is given in Chap.6. The circuit diagram of the receiver board is shown on sheet 1 of drawing C99088/01; the logic diagram is shown on sheet 2.

2. The components of the logic diagram comprise a bi-stable flip-flop (F1, sheet 2), two delay circuit-elements (A1 and A2, sheet 2), four NAND-gating elements (G1, G2, G4 and G5, sheet 2), two NAND inverter and power amplifier circuit-elements (G3 and G6, sheet 2) and a converter from negative to positive logic (A3, sheet 2). These components are mounted on the receiver board. Each bi-stable circuit and the associated delay circuits provide one stage of the "receiver ' ring counter in the receiver system of the station selection digital system (Part 12, Chap.3). The NAND-gates and inverter amplifiers provide logical gating, pulse inversion and amplification of the pulses throughout the receiver system (Part 12, Chap.3).

Bi-stable circuit and delayed outputs

3. The operation of the bi-stable circuit, which is formed by VT2, VT3 (sheet 1) and associated components, is similar in operation to the bi-stable circuit of the station board (Chap.6E). The two delay circuit-elements (VT4 and VT5, sheet 1) are similar in operation to the delay circuit-elements on the station board.

NAND circuit-elements

4. The NAND circuit-elements G1 to G6 are given in sheet 2. The operation of the NAND circuit-element G1, which provides inversion and amplification of the bi-stable trigger-pulse, is similar to the operation of the bi-stable trigger-pulse circuit on the station board (Chap.6E).

5. The NAND-gate circuit-element G2 (sheet 2) is formed by VT9 (sheet 1) and associated components. An output from the 'set' side of the bi-stable circuit (VT2 collector) is fed, via diode MR36, as one input to the gate. Other gating inputs are provided by MR35, MR37 and MR38 (pins S, R and P, respectively). When all these inputs to the gate are negative (logical '1'), all the input-diodes are rendered non-conducting and the resultant negative bias-voltage, derived originally from the -28V line, is fed via R31 and R32, the base-input-switching diode MR21, to the base of VT9 and switches this transistor into conduction. The output from VT9 collector (pin U) is, therefore, 0V (logical '0').

6. The output from VT9 collector causes diode MR22 to conduct, thus cutting-off the emitter-follower stage VT10, which is the first stage of a high-power NAND inverter amplifier (G3, sheet 2); the resultant positive voltage from the emitter

of VT10 (sheet 1) cuts off the second (power output) stage, VT11. The negative voltage (logical '1') from the collector of VT11 is fed to pin N. A description of a typical high-power NAND circuit-element is given in Chap.6C.

7. The NAND-gate circuit-element G4 (sheet 2) is formed by transistor VT12 and the associated components (sheet 1). Two inputs to G4 (which are also common to G2) are fed to the gate from pins S and R, via diodes MR27 and MR26, respectively. When both inputs are negative (logical '1'), transistor VT12 conducts and the output (pin K) is, therefore, 0V (logical '0').

8. The NAND-gate circuit-element G5 (sheet 2), which is formed by VT13 and associated components (sheet 1), is fed with three inputs. One input is provided by the output of G4, via diode MR29; a second input is fed, via MR30, from the collector of the bi-stable transistor VT2 (the bi-stable is set when VT2 is not conducting); the third input (common to G2) is fed, via MR25, from pin P.

9. When all these inputs are negative (logical '1'), transistor VT13 conducts and the collector output (logical '0') is fed to pin L and via MR32, to the two stage high-power NAND circuit-element G6 (sheet 2) consisting of VT14, VT15 and the associated components (sheet 1). Diode MR32 conducts and the potential (logical '0') at the junction of R54 and R49 causes the emitter-follower stage, VT14, to cut-off; the resultant positive potential, fed from VT14 emitter, biases the power stage (VT15) to cut-off; the output from VT15 (pin M) is, therefore, a negative potential (logical '1'). Detailed descriptions of the general NAND and high-power NAND circuit-elements are given in Chap.6B and 6C, respectively.

Converter from negative to positive logic

10. The converter circuit-element A3 (sheet 2) is formed by transistors VT6, VT7 and VT8 and associated components (sheet 1). The input to the converter is fed from the collector of the bi-stable transistor circuit of VT2, via MR15; the output is fed from the collector of VT8 to pin T. The converter is used to provide the necessary positive-logic output to feed the receiver frequency-encoders and frequency-busbars in the station selection digital system (Part 12, Chap.3). When the bi-stable circuit is in the 'set' state, the output from VT2 collector is negative (logical '1'); diode MR15 is, therefore, non-conducting and the negative voltage (logical '1'), at the junction of R21 and R22, causes VT6 to conduct (via MR16). The output voltage (0V) at the collector of VT6 results in a positive potential at the base of VT7; this potential is

derived from the network R27, MR19 and R24, and biases VT7 to cut-off. The collectors of VT6 and VT7 are supplied with -28V via resistors R23 and R25, respectively; during the negative excursions of the waveform at these collectors, the collector voltages are limited to -12V by diodes MR17 and MR18, respectively.

11. The last stage of the converter employs a grounded-emitter NPN-type transistor VT8, and with VT7 cut off (bi-stable circuit set), the negative base-bias voltage derived from the potential-divider network R25, R26 and R28, holds VT8 cut off. The collector of VT8 is fed from the +28V supply line, via resistors R29 and R30 and, with VT8 cut off, the collector output voltage (pin T) is limited to +12V by diode MR20. When VT7 is conducting (bi-stable circuit reset), the resultant potential of 0V at VT7 collector ensures that VT8 conducts (due to the positive base-bias voltage which is derived from the +12V supply line, via the potential-divider resistors R28 and R26).

Power supplies required

12. The power supplies required for the receiver board are, approximately, as follows:

(1)	-28V	-	300mA
(2)	+28V	-	100mA
(3)	-12V	-	20mA
(4)	+12V	-	100mA
(5)	+6V	-	30mA.

Test procedure

13. Tests of the logical operation of the bi-stable flip-flop and its associated delay circuit-elements, NAND-gating elements and inverter amplifiers, are implemented by first applying the coded positive and negative input-voltages and then setting or resetting the bi-stable flip-flop by a single shot trigger-pulse from the digital board test equipment. The resultant d.c. output voltages are then indicated by meter M1 on the test equipment front panel. The following test equipment is required.

(1) Digital board test equipment (G.P.S. Part No. A98079/A)
(2) -28V, +28V and 240V, 50/60c/s supplies for the test equipment
(3) Multimeter.

All the controls mentioned in the test procedure instructions are situated on the test equipment unit.

14. Connect the power supplies (-28V, +28V and 240V, 50/60c/s) to the digital board test equipment and connect the multimeter between the SCOPE O/P A and EARTH terminals on the test equipment panel. Switch on the test equipment by means of the AC and 28V switches. Check the -12V and +12V supplies by operating the METER SW switch, sequentially, to the -1 (-12V) and +1 (+12V) positions. Check that the multimeter (d.c. range 25V) indicates -12V and +12V, respectively. If necessary, adjust the appropriate -12V or +12V control, in the power circuits within the test equipment unit, to obtain the correct indications on the multimeter; disconnect the multimeter from the SCOPE O/P A terminal and check that the voltage between pins AJ of SKT1 and SKT2 is within the limits +5·8V to +6·5V with respect to the EARTH terminal. Switch off the test equipment, disconnect the multimeter, and plug the receiver board into SKT1 or SKT2.

15. Set the coding switches, initially, to the positions shown in Table 1.

Note...
It is important to maintain the correct sequence when setting the coding switches, switching on the test equipment and operating the SINGLE SHOT switch. The test equipment must not be switched off, nor must the board be removed from the test equipment, before the completion of all tests.

Switch on the test equipment and operate the SINGLE SHOT switch. Implement the tests according to the instructions given in sub-para. (1) to (9) inclusive.

TABLE 1

Coding switch positions A - FF1, G1 to G6, A1 to A3, MR5 and MR6

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	0	0	0	2	0	1	0	0	4

(1) Set the SCOPE AND METER SELECTOR switch, in turn, to the positions shown in column 1 of Table 2, the METER SW to the positions shown in column 2 and the LOAD SELECTOR to the positions shown in column 3. Operate the READ switch as instructed in column 4 (test A) and observe that, in each instance, the meter M1 indication is as shown in column 2 (+1, 0 or -1). Where the READ and LOAD instructions in column 5 (test B) are indicated, these operations must be performed in addition to the instructions given in column 4, and the meter M1 indication must, in each instance, remain as shown in column 2.

TABLE 2

Test equipment switch positions A

SCOPE AND METER SELECTOR:	METER SW and M1 indication:	LOAD SELECTOR:	Test A READ:	Test B READ and LOAD:	Component tested:
K	0	-	READ	-	G4
L	-1	-	READ	-	G5
M	0	-100	READ	READ and LOAD	G6
N	-1	-100	READ	READ and LOAD	G3
T	+1	12	READ	READ and LOAD	G1
U	0	-	READ	-	G2
V	0	-1	READ	READ and LOAD	A2
W	0	-	READ	-	FF1
X	-1	-	READ	-	A1
Z	-1	-	READ	-	FF1
AB	-1	-	READ	-	MR5
AC	-1	-	READ	-	MR6

(2) Set the coding switches to the positions shown in Table 3 and operate the SINGLE SHOT switch.

TABLE 3

Coding switch positions B - G2 to G6

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	0	0	0	0	0	0	0	1	0	0	4

(3) Carry out the tests as described in sub-para. (1) but, in this instance, use the test equipment switch positions given in Table 4.

TABLE 4

Test equipment switch positions B

SCOPE AND METER SELECTOR:	METER SW and M1 indication:	LOAD SELECTOR:	Test A READ:	Test B READ and LOAD:	Component tested:
K	-1	-	READ	-	G4
L	0	-	READ	-	G5
M	-1	-100	READ	READ and LOAD	G6
N	0	-100	READ	READ and LOAD	G3
U	-1	-	READ	-	G2

(4) Set the coding switches to the positions shown in Table 5 and operate the SINGLE SHOT switch.

TABLE 5

Coding switch positions C - G2 to G6

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	0	0	0	0	0	2	0	1	0	0	4

(5) Carry out the tests as described in sub-para. (1) but, in this instance use the test equipment switch positions given in Table 6.

TABLE 6

Test equipment switch positions C

SCOPE AND METER SELECTOR:	METER SW and M1 indication:	LOAD SELECTOR:	Test A READ:	Test B READ and LOAD:	Component tested:
K	-1	-	READ	-	G4
L	0	-	READ	-	G5
M	-1	-100	READ	READ and LOAD	G6
N	0	-100	READ	READ and LOAD	G3
U	-1	-	READ	-	G2

(6) Set the coding switches to the positions shown in Table 7 and operate the SINGLE SHOT switch.

TABLE 7

Coding switch positions D - G2 to G6

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	0	0	0	0	0	2	0	1	0	0	4

(7) Carry out the tests described in sub-para. (1) but, in this instance, use the test equipment switch positions shown in Table 8.

TABLE 8

Test equipment switch positions D

SCOPE AND METER SELECTOR:	METER SW and M1 indication:	LOAD SELECTOR:	Test A READ:	Test B READ and LOAD:	Component tested:
K	0	-	READ	-	G4
L	-1	-	READ	-	G5
M	0	-100	READ	READ and LOAD	G6
N	0	-100	READ	READ and LOAD	G3
U	-1	-	READ	-	G2

(8) Set the coding switches to the positions shown in Table 9 and operate the SINGLE SHOT switch.

TABLE 9

Coding switch positions E - FF1, G1 to G6, A1 to A3, MR5 and MR6

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	0	0	0	1	0	2	0	0	4

(9) Carry out the tests described in sub-para. (1) but, in this instance, use the test equipment switch positions shown in Table 10.

TABLE 10

Test equipment switch positions E

SCOPE AND METER SELECTOR:	METER SW and M1 indication:	LOAD SELECTOR:	Test A READ:	Test B READ and LOAD:	Component tested:
K	0	-	READ	-	G4
L	-1	-	READ	-	G5
M	0	-100	READ	READ and LOAD	G6
N	0	-100	READ	READ and LOAD	G3
T	0	-6	READ	READ and LOAD	G1
U	-1	-	READ	-	G2
V	-1	-	READ	-	A2
W	-1	-	READ	-	FF1
X	0	-1	READ	READ and LOAD	A1
Z	0	-	READ	-	FF1
AB	0	-	READ	-	MR5
AC	0	-	READ	-	MR6

(10) Switch the test equipment off and disconnect the receiver board.

Chapter 6G

FREQUENCY COMPARATOR BOARD

List of Contents

List of Tables

List of Illustrations

Frequency comparator board

1. An introduction to the digital-board descriptions is given in Chap.6. The circuit diagram of the frequency comparator board is shown on sheet 1 of drawing C99090/01; the logic diagram being shown on sheet 2.

2. The following circuit-elements are mounted on the frequency comparator board:

(1) A multiple-input OR gate (G1, sheet 2)
(2) Ten pairs of comparison (summing)resistors (A1, A3, A5, A7, A9, A11, A13, A15, A17 and A19, sheet 2)
(3) Ten inverter amplifiers (A2, A4, A6, A8, A10, A12, A14, A16, A18 and A19, sheet 2)
(4) A three-input OR gate (G2, sheet 2).

3. The outputs from the comparison resistors and inverters provide a total of twenty inputs to the diodes of the OR-gate (G1). The inputs to the pairs of comparison resistors are fed from the receiver-frequency and station-frequency busbars in the station selection digital system (Part 12, Chap. 3); one resistor in the pair is fed by an input provided by a station-frequency busbar, the input to the other resistor being provided by a receiver-frequency busbar. It is important to note that the potential applied to one comparison resistor (receiver busbar) varies between approximately +12V and approximately 0V; the potential applied to the other comparison resistor (station busbar) varies between approximately -12V and approximately 0V.

Multiple-input OR-gate

4. The OR-gate (G1, sheet 2) is formed by resistor R41 and diodes MR1, 3, 4, 6, 7, 9, 10, 12, 13, 15, 16, 18, 19, 21, 22, 24, 25, 27, 28 and 30; the anodes of all these diodes are connected to resistor R41 which is supplied from the +12V supply line. The outputs from the pairs of comparison resistors and inverter amplifiers determine the cathode potentials of the diodes which comprise the OR-gate.

Comparator circuit

5. Two comparison resistors (e.g., A1, sheet 2) and one inverter amplifier (A2, sheet 2), together with two of the OR-gate diodes (MR1 and MR3, sheet 1), form a binary one-bit comparator circuit. There are ten identical, one-bit, comparator circuits on the board.

6. The input voltages to an individual comparator circuit, from the station-frequency busbar, must be regarded as a logical '1' when the busbar potential is negative (-12V), and as a logical '0' when the busbar potential is 0V (negative logic); the input-voltages from the receiver-frequency busbar must be regarded as a logical '1' when the busbar is positive (+12V), and as a logical '0' when the busbar is 0V (positive logic). When both the inputs are in the same logical state (either both logical '1' or both logical '0'), the output from the multiple OR-gate is a logical '0' (0V); when the inputs are dissimilar, the OR-gate output is a logical '1' (negative).

The operation of one comparator circuit consisting of VT1, MR1, MR3 and the associated components (sheet 1) is described.

7. Assuming that pin AD (sheet 1) is at a potential of -12V (station busbar, logical '1'), and pin AC is at a potential of +12V (receiver busbar, logical '1'), then the potential at the junction of the comparison resistors R1 and R2 is 0V and, consequently, diode MR1 conducts; the output of the OR-gate (pin A) is, therefore, 0V (logical '0'). Identical circuit conditions exist if both pins AD and AC are at a potential of 0V (logical '0'). When the potential at the junction of R1 and R2 is 0V, the inverter amplifier transistor VT1 is conducting, due to the negative base-bias potential derived, via R4, from the -12V supply line. When VT1 is conducting, MR3 provides a conducting path from the +12V supply, via R41 and VT1, to earth (0V).

8. When the input-potentials to the comparison resistors are dissimilar, the comparator circuit operates as follows:

(1) With pin AD at a potential of -12V (logical '1'), and pin AC at a potential of 0V (logical '0'), the resultant negative voltage (approximately -6V) at the junction of R1 and R2 causes MR1 to conduct, thus "clamping" the OR-gate output (pin A) to this negative input potential (-6V).

Note...

The -6V output of the OR-gate is applied, usually, to an inverter stage which must recognise this voltage (-6V) as a logical '1'.

(2) With pin AD at a potential of 0V (logical '0'), and pin AC at a potential of +12V (logical '1'), diode MR1 is non-conducting but the base-input-switching diode, MR2, conducts, and the resultant positive voltage (derived from the divider network R2, MR2 and R4), is applied to the base of VT1 and causes this transistor to cut off; thus, the OR-gate output (pin A) is "clamped", via MR3, to the negative potential (logical '1') at the collector of VT1.

Station frequency word-length

9. Two frequency-comparator boards are used in the station selection digital system (Part 12, Chap.3) and the OR-gate outputs (pins A) of each board are commoned'. This connection provides a comparator circuit suitable for a total of twenty binary-bits and this circuit is sufficient to accommodate the length of the nineteen-bit word which represents the station frequency (Part 12, Chap.3).

10. The OR-gate (G2, sheet 2) formed by diodes MR31, 32 and 33 (sheet 1) is not used in the station selection digital system.

Power supply requirements

11. The power supplies required for the frequency comparator board are as follows:

(1) +12V - 75mA
(2) -12V - 75mA
(3) + 6V - 15mA (signal input).

Test procedure

12. The test procedure consists of checks of the comparator circuits by the application of coded input-voltages to the comparison resistors of the frequency comparator board. The resultant OR-gate output indications are checked on the meter (M1) and on the DM160-type LEVEL INDICATOR, both of which are located on the front panel of the test equipment. The following test equipment is required:

(1) Digital board test equipment (G.P.S. Part No. A98079/A)
(2) -28V, +28V and 240V, 50/60c/s supplies for the test equipment
(3) Multimeter.

All the controls mentioned in the test procedure instructions are situated on the test equipment unit.

13. Connect the power supplies (-28V, +28V and 240V, 50/60 c/s) to the digital board test equipment, and connect the multimeter between the SCOPE O/P A and EARTH terminals on the test equipment panel. Switch on the test equipment by means of the AC and 28V switches. Check the -12V and +12V supplies by operating the METER SW switch to the -1 (-12V) and +1 (+12V) positions, in turn. Check that the multimeter (d.c. range 25V) indicates -12V and +12V, respectively. If necessary, adjust the appropriate -12V or +12V control, in the power circuits within the test equipment unit, to obtain the correct indications on the multimeter; disconnect the multimeter from the SCOPE O/P A terminal and check that the voltage between pins AJ of SKT1 and SKT2 is +5·8V to +6·5V with respect to the EARTH terminal. Switch off the test equipment, disconnect the multimeter, and plug the frequency comparator board into SKT1 or SKT2.

14. Set the coding switches to the positions shown in Table 1. Switch on the test equipment and carry out the tests according to the instructions given in sub-para. (1) to (8) inclusive.

TABLE 1

Coding switch positions A

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	1	1	2	0	0	2	3	2	3	2	3	2	3	2	3	3	2	3	2	3	2	3	2	3	2

(1) Set the SCOPE AND METER SELECTOR switch to position A (OR-gate G1 output) and the METER SW to 0; operate the READ switch and check that meter M1 indicates 0 (component tested, G1). Set the SCOPE AND METER SELECTOR switch to position E, the METER SW to -1, the LOAD SELECTOR to +6 and operate the LOAD and READ switches together. Check that the meter indication is -1 (component tested, G2).

(2) Switch off the test equipment and set the coding switches to the positions shown in Table 2.

TABLE 2

Coding switch positions B

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	1	2	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

(3) Switch on the test equipment, set the SCOPE AND METER SELECTOR switch to A and the METER SW to 0; operate the READ switch and check that meter M1 indicates 0 (component tested G1). Set the SCOPE AND METER SELECTOR to E, the METER SW to -1, the LOAD SELECTOR to +6; operate the LOAD and READ switches together and check that meter M1 indicates -1 (component tested, G2).

(4) Switch off the test equipment and set the coding switches to the positions shown in Table 3.

TABLE 3

Coding switch positions C

Coding switch:	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
Code:	0	2	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3

(5) Switch on the test equipment, set the SCOPE AND METER SELECTOR switch to A and the METER SW to -1; operate the READ switch and check that meter M1 indicates -1 (components tested, G1, A1 and A2). Set the SCOPE AND METER SELECTOR to E, the METER SW to -1, the LOAD SELECTOR to +6; operate the LOAD and READ switches together and check that meter M1 indicates -1 (component tested, G2). Switch off the test equipment.

(6) With the SCOPE AND METER SELECTOR set to A and the METER SW set to -1, continue to test the remaining circuit-elements of the frequency comparator board by setting the coding switches to the different combinations given in Table 4, in turn. For each of the coding switch positional combinations shown in the Table, switch on the test equipment, operate the READ switch and check that meter M1 indicates -1.

Note...

Switch off the test equipment before changing the coding switches from one given combination to another; then, after selecting the coding switch combination, switch on the test equipment, operate the READ switch and check that meter M1 indicates -1.

TABLE 4

Coding switch positions D

Coding switch: A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	Component tested:
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	A3, A4
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1	1	A5, A6
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	A7, A8
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1	A9, A10
0	0	0	0	0	0	1	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	A11, A12
0	0	0	0	0	0	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	A13, A14
0	0	0	0	0	0	1	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	A15, A16
0	0	0	0	0	0	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	A17, A18
0	0	0	0	0	0	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	A19, A20

(7) Switch off the test equipment and, with the SCOPE AND METER SELECTOR switch set to A, set the coding switches to the different combinations given in Table 5, in turn. For each of these coding switch positional combinations, operate the LEVEL INDICATOR switch and check that the LEVEL INDICATOR lamp on the test equipment front panel remains extinguished.

Note...

Swith off the test equipment before changing the coding switches from one given combination to another; then, after selecting the coding switch combination, switch on the test equipment, operate the LEVEL INDICATOR switch and check that the LEVEL INDICATOR lamp is extinguished.

(8) Switch off the test equipment and remove the frequency comparator board.

TABLE 5

Coding switch positions E

A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	Component tested:
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	A1, A2
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	A3, A4
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	A5, A6
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	A7, A8
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	A9, A10
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	A11, A12
0	0	0	0	0	0	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	A13, A14
0	0	0	0	0	0	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	A15, A16
0	0	0	0	0	0	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	A17, A18
0	0	0	0	0	0	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	A19, A20

Chapter 6H

FEEDBACK BOARD (FB626)

List of Contents

List of Illustrations

Feedback board (FB626)

1. The circuit of the feedback board (FB626) is shown on drawing C208469/01. The feedback board is located in position 21BD/T3 and contains four single diodes, two pairs of diodes, each pair of which is connected as an AND-gate, and a four-stage transistor inverter-amplifier.

2. The single diodes MR4, 7, 8 and 9, are not used in the station selection digital system. The two AND-gates, consisting of diodes MR2 and MR3, and MR5 and MR6, respectively, provide the NAND-gate inputs to the NAND circuit-elements 21BD/M/G1 and /G3 in the station and receiver ring-counter system (Part 12, Chap.3). The input of the inverter amplifier (21BD/T3) is connected to the output of the OR-gates (21BD/J/G1 and /K/G1) in the digital frequency-comparator (Part 12, Chap.3). The output of the amplifier provides the power for the "in tune" busbar in the station selection digital system (Part 12, Chap.3).

Amplifier circuit description

3. The h.t. supplies, which are externally connected to PL1 on the feedback board FB626, are as follows:

(1) -12V (PL1/4) - 10mA (approximately)
(2) + 6V (PL1/27) - 5mA (approximately).

Pin 29 on PL1 is normally connected to earth potential (0V).

4. The emitter-follower input stage (VT1) is fed from the output of the frequency comparator (Chap.6G) OR-gate, via pins 1 and 2. The output from the emitter of VT1 (R1) is fed to the base of the grounded-emitter stage VT2, and the resultant amplified d.c. voltage provides the input to the base of the second grounded-emitter stage, VT3. The output from VT3 collector is fed to the base of output-transistor VT4, via resistor R8 and the base-input-switching diode MR1. The +6V positive bias potential is fed to the bases of VT2, VT3 and VT4 via resistors R3, R6 and R9 respectively. The bias potential ensures that VT2, VT3 and VT4 cut off sharply when 0V is applied to their associated base-input resistors R2, R5 and R8.

5. A negative voltage input to the base of VT1 results in a negative voltage at VT1 emitter (R1) and an output of 0V at the collector of VT4 (PL1/31 and /32).

Test procedure

6. The test procedure of the feedback board consists of a d.c. check of the amplifier output for a given d.c. input voltage. The test is implemented with the aid of a multimeter.

7. Connect the following h.t. supplies to the feedback board:

(1) -12V to pin 4 of PL1
(2) + 6V to pin 27 of PL1.

Connect the digital system earth (0V) to pin 29 of PL1.

8. Connect PL1/1 and /2 to PL1/29 and check, with the aid of the multimeter, that the voltage at PL1/31 and /32 is -12V. Disconnect PL1/1 and /2 from PL1/29 and connect PL1/1 and /2 to PL1/4; check, with the aid of the multimeter, that the voltage at PL1/31 and /32 reduces to zero.

Chapter 7A

AUDIO AMPLIFIER TYPE 506

List of Contents

List of Illustrations

General

1. The audio amplifier type 506 is a general-purpose transistorized a.f. amplifier used in intercom and radio aids audio systems. The unit can be used as a microphone pre-amplifier when its output is connected, normally via a 10-kilohm summing resistor, to a second (similar) unit for further amplification. A number of audio signals can be mixed at the input of the amplifier via external 10-kilohm summing resistors.

2. The amplifier output can be connected to various combinations of headsets or to a monitoring loudspeaker. An output transformer having secondary tappings of 75, 150, and 600 ohms is used to match the amplifier output to these various loads.

3. The intercom amplifier unit is mounted on a printed circuit board.

Circuit description (C54254/01)

4. The first stage of the amplifier VT1 (AC107), is a common emitter amplifier directly-coupled to the driver transistor, VT2 (ACY21). The emitter load of VT1 is only partially decoupled by C2, via R3, which provide series negative feedback to the first stage.

5. Capacitor C4 is connected across the input of VT2 to reduce the high-frequency response of the amplifier. An input impedance of 100 ohms is obtained by applying negative feedback, from the junction of R6 and R7, to the base of VT1, via R5. This also improves the stability of the first two stages.

6. Phase-splitting is achieved by transformer T1, the two secondary windings of which drive the output stage transistors VT3 and VT4 (ACY21).

7. The output stage is a split-load, class B, push-pull power amplifier, transformer-coupled to the external load of 75, 150, or 600 ohms. The maximum power output of 500mW can be reduced, if desired, to 75mW by connecting an external 3·3-kilohm resistor across the driver-transformer secondary windings, via PL1/23 and PL1/25. Capacitor C5 provides further h.f. attenuation of the overall response of the amplifier.

8. The supply for the amplifier is stabilized at, nominally, -9·1V by Zener diode MR1 (OAZ227), the supply voltage from the -28V line being reduced to this value by R10 and R11.

9. The voltage across the output transformer T2 secondary winding, relative to the zero-ohm connection, is arranged to be in anti-phase to the input signal voltage.

Power supply

10. Power supply requirement for the audio amplifier unit is -28V d.c. at 125mA.

Performance details

11. The unit is capable of 500mW output with a 1V r.m.s., 1kc/s sinewave signal applied to the input via an external 10-kilohm resistor. The overall frequency response is 3dB down at approximately 200c/s and 3·7kc/s. This frequency response is extended if a 3·3-kilohm resistor is connected to PL1/23 and PL1/25.

12. Total hum and noise content is approximately 100dB down, relative to 75mW output, with the input short-circuited.

Test procedure

13. The gain of the amplifier is measured at 1kc/s, the phase relationship between input and output observed, and the power supply stabilization checked. The equipment required for these tests is as follows:

(1) A.F. signal generator
(2) Oscilloscope
(3) Multimeter
(4) 150-ohm, ±5 per cent, 0·5-watt resistor
(5) 10-kilohm, ±5 per cent, 0·5-watt resistor
(6) 3·3-kilohm, ±5 per cent, 0·5-watt resistor.

14. Connect the 150-ohm resistor between PL1/9 and PL1/16. Connect PL1/15 to PL1/18, and PL1/27 to PL1/19.

15. Connect a -28V d.c. supply to PL1/1, using PL1/20 as the earth return. Switch on the power supply and check with the multimeter that the voltage across Zener diode MR1 is between -8·6V and -9·6V relative to PL1/19.

16. Apply a 1kc/s sinewave from the a.f. signal generator output, in series with a 10-kilohm resistor, to the input of the amplifier, PL1/31. Connect the oscilloscope across the 150-ohm resistor and observe the waveform. Adjust the output voltage of the a.f. signal generator until the waveform across the 150-ohm resistor is just below distortion level. The amplitude of this waveform must be not less than 7·7V peak-to-peak.

17. Measure the input waveform at the output of the a.f. signal generator, using the oscilloscope. The amplitude must not be greater than 1·4V peak-to-peak.

18. Connect the 3·3-kilohm resistor between PL1/23 and PL1/25. Check that the output voltage is reduced to approximately 2·7V peak-to-peak.

19. Using the oscilloscope, check that the input waveform (PL1/31) and the output waveform (PL1/9) are in anti-phase.

Chapter 7B

AUDIO AMPLIFIER TYPE 507

List of Contents

List of Tables

List of Illustrations

General

1. The audio amplifier type 507 consists of a transistorized high-gain a.f. amplifier, suitable either for tape replay purposes or for use as a microphone pre-amplifier. The amplifier and its 20V series-regulator power supply are contained in a screening can; connection to the external circuit is made by flying leads.

Circuit description (C208711/01)

2. Transformer T1 matches the impedance of the tape recorder replay head to the input impedance of transistor VT1 (C111). Transistors VT1, VT2 (C111) and VT3 (C111) form a directly-coupled, high voltage-gain, amplifier, the output of the amplifier being taken from VT3 collector, via C4, to the output transformer T2.

3. Negative d.c. feedback from VT3 collector to VT1 base, via resistor R8, ensures stable d.c. operating conditions. Resistor R8, in conjunction with R9, also provides base bias for VT1. The absence of emitter-load decoupling capacitors for VT1 and VT2, and the partial decoupling of VT3 emitter, also contribute to the overall stability and linearity of the amplifier.

4. The bandwidth of the audio amplifier type 507 is (nominally) 250c/s to 2kc/s. The lower frequency limit is determined by the physical sizes of the input- and output-transformers; the high-frequency response is limited to 2kc/s, by capacitor C2, to reduce the amplifier noise level.

5. The collector supply voltage for VT1, VT2, and VT3 is obtained from the emitter of series-regulator transistor VT4 (2N3053). VT4, together with Zener diode MR2 and resistor R11, regulates this supply at +20V d.c. The common return line for the emitter loads of VT1, VT2, and VT3 is maintained at +5·6V d.c. by Zener diode MR1, this potential being obtained from the +20V line via resistor R10.

Power supply

6. The power supply requirement for the audio amplifier type 507 is +28V d.c. at 15mA.

Voltage checks

7. Typical transistor voltages, measured with respect to lead B by means of a multimeter, are given in Table 1.

TABLE 1

Typical transistor voltages

Transistor:	Electrode:	Voltage:
VT1 (C111)	collector	+ 7·5V
VT2 (C111)	collector	+ 8·5V
VT3 (C111)	collector	+ 11·0V
VT4 (2N3053)	emitter	+ 20V

Performance details

8. The unit is capable of providing an undistorted 1V peak-to-peak output for an input of 1mV within a bandwidth of 250c/s to 2kc/s.

Test procedure

9. The following equipment is required for testing the audio amplifier type 507:

(1) Oscilloscope
(2) Multimeter
(3) A.F. signal generator
(4) 560-ohm, +10 per cent, 0·25-watt resistor.

10. Connect the power supply to the amplifier type 507 as follows:

(1) Lead A - +28V d.c.
(2) Lead B - power supply earth.

Switch on the power supply and, using the multimeter, check that the transistor voltages are as given in Table 1

11. Switch off the power supply and connect the 560-ohm resistor between lead G and lead H. Connect the a.f. signal generator output to leads C and D and set its frequency to 1000c/s. Connect the input to the oscilloscope across the 560-ohm resistor, and switch on the power supply. Increase the a.f. signal generator output amplitude from zero to approximately 1mV and check, using the oscilloscope, that an undistorted sinewave output of 1V peak-to-peak is obtained.

Chapter 7C

AUDIO AMPLIFIER TYPE 508

List of Contents

List of Tables

List of Illustrations

General

1. The audio amplifier type 508 provides amplification of audio frequency signals for driving a magnetic tape recording head. The bandwidth of the amplifier is set to give an adequate simulation of normal aircraft R/T quality in a typical audio system. The amplifier, and its +20V series-regulator power supply, are contained in a cylindrical screening can; external connections are made by flying leads.

Circuit description (C208712/01)

2. The circuit of the audio amplifier type 508 comprises a two-stage, direct-coupled amplifier which includes an overall a.c. and d.c. negative feedback loop. Input- and output-transformers provide circuit isolation; the input transformer primary and the output transformer secondary are centre-tapped for balanced operation.

3. The input to the amplifier is coupled to the base of VT1 (OC139) via input transformer T1, capacitor C2 and resistor R1. The amplified signal at VT1 collector is direct-coupled to the input emitter follower VT2, (OC139), thus providing current amplification. The output current is fed to the primary of T2 via capacitor C1. The amplifier output is taken from the secondary of T2 via leads G, H, and K (centre-tap).

4. The amplifier bandwidth is approximately 200c/s to 10kc/s, these limits being determined mainly by the characteristics of the input and output transformers. The input impedance, at the primary of T1, is 600 ohms; the normal output load, when the amplifier is used in conjunction with the bias oscillator (Chap. 7J), is 1 kilohm.

5. Transistor VT3, Zener diode MR2, and resistor R7 provide a regulated +20V d.c. supply for the circuit, this voltage being derived from the +28V d.c. supply to the amplifier unit. The common return for T1 secondary, VT1 emitter, VT2 emitter, and T2 primary is maintained at +3·3V by Zener diode MR1 and resistor R6.

Power supply

6. The power supply requirement for the audio amplifier type 508 is +28V d.c. at 25mA.

Voltage checks

7. Typical transistor voltages, measured with respect to lead B by means of a multimeter, are given in Table 1.

TABLE 1

Typical transistor voltages

Transistor:	Electrode:	Voltage:
VT1 (OC139)	emitter	+ 3·3V
	collector	+ 11V
VT3 (2N3053)	emitter	+ 20V

Performance details

8. The unit is capable of providing an undistorted 2V peak-to-peak output for an input of 0·25V within a bandwidth of 200c/s to 10kc/s.

Test procedure

9. The following test equipment is required when testing the audio amplifier type 508:

(1) Oscilloscope
(2) Multimeter
(3) A.F. signal generator.

10. Connect the power supply to the amplifier type 508 as follows:

(1) Lead A - +28V d.c.
(2) Lead B - power supply earth.

Switch on the power supply and, using the multimeter, check that the transistor voltages are as given in Table 1.

11. Connect the a.f. signal generator output to leads C and D of the amplifier under test, and set the output of the signal generator to 0·25V peak-to-peak (as observed on the oscilloscope) at a frequency of 1kc/s. Connect the oscilloscope input to leads G and H (amplifier output) and check that the displayed output waveform is an undistorted sinewave of approximately 2V peak-to-peak.

Chapter 7D

400 C/S OSCILLATOR TYPE 315

List of Contents

List of Tables

List of Illustrations

General

1. The oscillator type 315 is a 400c/s Wien-bridge oscillator, suitable for use as an audio tone-generator. The circuit possesses a high degree of frequency- and amplitude-stability, the output being independent of moderate changes in ambient temperature. The circuit supply is filtered and stabilized to render the oscillator insensitive to fluctuations in the -28V d.c. line and to prevent oscillations being fed into the d.c. supplies.

Circuit description (C54233/01)

2. Transistors VT1 and VT2 form a directly-coupled two-stage amplifier, which provides the zero phase-shift required by the Wien-bridge circuit. VT2 is directly-coupled to VT3, which is an emitter follower supplying the output signal and the frequency-determining R-C network, via capacitor C1.

3. Capacitors C2 and C3 are the reactive components of the series and parallel arms of the Wien-bridge which, in conjunction with resistors R6 to R9 and R10 to R13, determine the oscillator frequency. The feedback loop is taken from the junction of C2 and R10 to the base of VT1. Resistors R10 to R13 also provide, with R14, the bias-stabilizing network for the base of VT1.

4. Negative d.c. and a.c. feedback is applied from VT2 collector to VT1 emitter via resistor R2, thus improving d.c. stability and reducing harmonic distortion.

5. Negative feedback is also applied from the output coupling capacitor C1, via RV1 and thermistor TH1, to the tapped load (R3 and R4) of VT1 emitter. When the oscillator is first switched on, thermistor TH1 is cold and its resistance is at a maximum. The loop gain of the oscillator is, therefore, initially high.

6. As the oscillations build up, the output amplitude and the power dissipated in TH1 increase. The resistance of TH1 falls, causing an increase in the signal fed back to VT1 emitter, thus reducing the loop gain. This action continues until stable operating conditions are reached.

7. The normal output is 1·2V r.m.s. but it can be adjusted from 1·1V to 1·8V r.m.s. by means of preset potentiometer RV1.

8. The d.c. supply voltage is stabilized at -12V by Zener diode MR1 and is decoupled by filter network R15, R16, C4 and C5.

Power supply

9. The power supply required for the oscillator type 315 is -28V d.c. at approximately 10mA.

Voltage checks

10. Table 1 gives typical static voltages for the circuit, measured with a multimeter with respect to earth.

TABLE 1

Transistor voltages

Transistor:	Voltage measured:	
	Collector:	Emitter:
VT1 (ASY27)	-11·5V	-1·25V
VT2 (2N1304)	-6·5V	-11·5V
VT3 (ASY27)	-11·5V	-6·5V
Across Zener diode MR1 (OAZ230) : -12V		

Performance details

11. The oscillator type 315 generates a 400 $\pm$12c/s undistorted sinewave of 1·2V r.m.s. amplitude.

Test procedure

12. To test the correct frequency, amplitude, and shape of the output waveform, the following equipment is required:

(1) Oscilloscope
(2) Valve voltmeter
(3) A.F. signal generator
(4) Multimeter
(5) 32-way edge-connector.

13. By means of the edge-connector, make connections to the oscillator circuit board as follows:

(1) PL1/10 - -28V d.c.
(2) PL1/1 - power earth return
(3) PL1/20 - signal output
(4) PL1/30 - signal earth return.

14. Switch on the power supply and, with the multimeter, check the static voltages given in Table 1.

15. Measure the r.m.s. signal output across PL1/20 and PL1/30 with the valve voltmeter, and adjust RV1 to obtain a reading of 1·2V.

16. Connect the output of the a.f. signal generator to the A2 input of the oscilloscope. Connect the oscillator signal output to the A1 input of the oscilloscope and adjust the a.f signal generator to give an output equal in frequency and amplitude to that of the oscillator.

17. The oscillator waveform must be an undistorted sinewave. By comparison with the waveform from the a.f. signal generator, measure the oscillator frequency. This must be 400c/s ±12c/s.

18. Adjust potentiometer RV1 and observe, on the valve voltmeter, that the amplitude of the oscillator output varies from 1·1V to 1·8V r.m.s., without noticeable distortion or change of frequency. Reset the output to 1·2V r.m.s. amplitude.

Chapter 7E

1020 C/S OSCILLATOR TYPE 316

List of Contents

List of Tables

List of Illustrations

General

1. The oscillator type 316 contains a 1020c/s Wien-bridge oscillator circuit which is used as an audio tone-generator. The circuit possesses a high degree of frequency and amplitude-stability, the output being independent of moderate changes in ambient temperature. The circuit supply is filtered and stabilized to render the oscillator insensitive to fluctuations in the -28V d.c. line, and to prevent oscillations being fed into the d.c. supplies.

Circuit description (C54234/01)

2. Transistors VT1 and VT2 form a directly-coupled amplifier, the two stages of which provide the zero phase-shift required by the Wien-bridge circuit. VT2 is directly-coupled to VT3, which is an emitter-follower supplying the output signal and the frequency-determining R-C network, via capacitor C1.

3. Capacitors C2 and C3 are the reactive components of the series and parallel arms of the Wien-bridge which, in conjunction with resistors R6 to R9 and R10 to R13 determine the oscillator frequency. The feedback loop is taken from the junction of C2 and R10 to the base of VT1. Resistors R10 to R13 also provide, with R14, the bias-stabilizing network for the base of VT1.

4. Negative d.c. and a.c. feedback is applied from VT2 collector to VT1 emitter via resistor R2, thus improving d.c. stability and reducing harmonic distortion.

5. Negative feedback is also applied from the output coupling capacitor C1, via RV1 and thermistor TH1, to the tapped load (R3 and R4) of VT1 emitter. When the oscillator is first switched on, thermistor TH1 is cold and its resistance is at a maximum; the loop gain of the oscillator is, therefore, initially high.

6. As the oscillations build up, the output amplitude and the power dissipated in TH1 increase. The resistance of TH1 falls, causing an increase in the signal fed back to VT1 emitter, thus reducing the loop gain. This action continues until stable operating conditions are reached.

7. The normal output is 1·2V r.m.s. but it can be adjusted from 1·1V to 1·8V r.m.s. by means of preset potentiometer RV1.

8. The d.c. supply voltage is stabilized at -12V by Zener diode MR1 and is decoupled by filter network R15, R16, C4 and C5.

Power supply

9. The power supply required for the oscillator type 316 is -28V d.c. at approximately 10mA.

Voltage checks

10. Table 1 gives typical transistor voltages for the circuit, measured with a multimeter with respect to earth.

TABLE 1

Transistor voltages

Transistor:	Voltage measured:	
	Collector:	Emitter:
VT1 (ASY27)	-11·5V	-1·25V
VT2 (2N1304)	-6·5V	-11·5V
VT3 (ASY27)	-11·5V	-6·5V
Across Zener diode MR1 (OAZ230):	-12V	

Performance details

11. The oscillator type 316 generates a 1020 $\pm$31c/s undistorted sinewave of 1·2V r.m.s. amplitude.

Test procedure

12. Tests are carried out to ensure the correct frequency, amplitude, and shape of the output waveform. For these tests, the following equipment is required:

(1) Oscilloscope
(2) Valve voltmeter
(3) A.F. signal generator
(4) Multimeter
(5) 32-way edge-connector.

13. By means of the edge-connector, make connections to the oscillator circuit board as follows:

(1) PL1/10 - -28V d.c.
(2) PL1/1 - power earth return
(3) PL1/20 - signal output
(4) PL1/30 - signal earth return.

14. Switch the power supply on and, with the multimeter, check that the static voltages are as given in Table 1.

15. Measure the r.m.s. signal output across PL1/20 and PL1/30 with the valve voltmeter, adjusting RV1 to obtain a reading of 1·2V.

16. Connect the output of the a.f. signal generator to the A2 input of the oscilloscope. Connect the oscillator signal output to the A1 input of the oscilloscope and adjust the a.f. signal generator to give an output equal in frequency and amplitude to that of the oscillator.

17. The oscillator waveform must be an undistorted sinewave. By comparison with the waveform from the a.f. signal generator, measure the oscillator frequency. This must be 1020c/s ±31c/s.

18. Adjust potentiometer RV1 and observe, on the valve voltmeter, that the amplitude of the oscillator output varies from 1·1V to 1·8V r.m.s., without noticeable distortion or change of frequency. Reset the output to 1·2V r.m.s. amplitude.

Chapter 7F

1300 C/S OSCILLATOR TYPE 317

List of Contents

List of Tables

List of Illustrations

General

1. The oscillator type 317 contains a 1300c/s Wien-bridge oscillator circuit which is used as an audio tone-generator. The circuit possesses a high degree of frequency and amplitude-stability, the output being independent of moderate changes in ambient temperature. The circuit supply is filtered and stabilized to render the oscillator insensitive to fluctuations in the -28V d.c. line, and to prevent oscillations being fed into the d.c. supplies.

Circuit description (C54235/01)

2. Transistors VT1 and VT2 form a directly-coupled amplifier, the two stages of which provide the zero phase-shift required by the Wien-bridge circuit. VT2 is directly-coupled to VT3, which is an emitter-follower supplying the output signal and the frequency-determining R-C network, via capacitor C1.

3. Capacitors C2 and C3 are the reactive components of the series and parallel arms of the Wien-bridge which, in conjunction with resistors R6 to R9 and R10 to R13 determine the oscillator frequency. The feedback loop is taken from the junction of C2 and R10 to the base of VT1. Resistors R10 to R13 also provide, with R14, the bias-stabilizing network for the base of VT1.

4. Negative d.c. and a.c. feedback is applied from VT2 collector to VT1 emitter via resistor R2, thus improving d.c. stability and reducing harmonic distortion.

5. Negative feedback is also applied from the output coupling capacitor C1, via RV1 and thermistor TH1, to the tapped load (R3 and R4) of VT1 emitter. When the oscillator is first switched on, thermistor TH1 is cold and its resistance is at a maximum; the loop gain of the oscillator is, therefore, initially high.

6. As the oscillations build up, the output amplitude and the power dissipated in TH1 increase. The resistance of TH1 falls, causing an increase in the signal fed back to VT1 emitter, thus reducing the loop gain. This action continues until stable operating conditions are reached.

7. The normal output is 1·2V r.m.s. but it can be adjusted from 1·1V to 1·8V r.m.s. by means of preset potentiometer RV1.

8. The d.c. supply voltage is stabilized at -12V by Zener diode MR1 and is decoupled by filter network R15, R16, C4 and C5.

Power supply

9. The power supply required for the oscillator type 317 is -28V d.c. at approximately 10mA.

Voltage checks

10. Table 1 gives typical transistor voltages for the circuit, measured with a multimeter with respect to earth.

TABLE 1

Transistor voltages

Transistor:	Voltage measured: Collector:	Emitter:
VT1 (ASY27)	-11·5V	-1·25V
VT2 (2N1304)	-6·5V	-11·5V
VT3 (ASY27)	-11·5V	-6·5V
Across Zener diode MR1 (OAZ230):	-12V	

Performance details

11. The oscillator type 317 generates a 1300 ±39c/s undistorted sinewave of 1·2V r.m.s. amplitude.

Test procedure

12. Tests are carried out to ensure the correct frequency, amplitude and shape of the output waveform. For these tests, the following equipment is required:

(1) Oscilloscope
(2) Valve voltmeter
(3) A.F. signal generator
(4) Multimeter
(5) 32-way edge-connector.

13. By means of the edge-connector, make connections to the oscillator circuit board as follows:

(1) PL1/10 - -28V d.c.
(2) PL1/1 - power earth return
(3) PL1/20 - signal output
(4) PL1/30 - signal earth return.

14. Switch the power supply on and, with the multimeter, check that the static voltages are as given in Table 1.

15. Measure the r.m.s. signal output across PL1/20 and PL1/30 with the valve voltmeter, adjusting RV1 to obtain a reading of 1·2V.

16. Connect the output of the a.f. signal generator to the A2 input of the oscilloscope. Connect the oscillator signal output to the A1 input of the oscilloscope and adjust the a.f. signal generator to give an output equal in frequency and amplitude to that of the oscillator.

17. The oscillator waveform must be an undistorted sinewave. By comparison with the waveform from the a.f. signal generator, measure the oscillator frequency. This must be 1300c/s ±39c/s.

18. Adjust potentiometer RV1 and observe, on the valve voltmeter, that the amplitude of the oscillator output varies from 1·1V to 1·8V r.m.s., without noticeable distortion or change of frequency. Reset the output to 1·2V r.m.s. amplitude.

Chapter 7G

3KC/S OSCILLATOR TYPE 318

List of Contents

List of Tables

List of Illustrations

General

1. The oscillator type 318 contains a 3kc/s Wien-bridge oscillator circuit which is used as an audio tone-generator. The circuit possesses a high degree of frequency- and amplitude-stability, the output being independent of moderate changes in ambient temperature. The circuit supply is filtered and stabilized to render the oscillator insensitive to fluctuations in the -28V d.c. line, and to prevent oscillations being fed into the d.c. supplies.

Circuit description (C54236/01)

2. Transistors VT1 and VT2 form a directly-coupled amplifier, the two stages of which are necessary to provide the zero phase-shift required by the Wien-bridge circuit. VT2 is directly-coupled to VT3, which is an emitter-follower supplying the output signal and the frequency-determining R-C network, via capacitor C1.

3. Capacitors C2 and C3 are the reactive components of the series and parallel arms of the Wien-bridge which, in conjunction with resistors R6 to R8 and R11 to R13 determine the oscillator frequency. The feedback loop is taken from the junction of C2 and R11 to the base of VT1. Resistors R11 to R13 also provide, with R14, the bias-stabilizing network for the base of VT1.

4. Negative d.c. and a.c. feedback is applied from VT2 collector to VT1 emitter via resistor R2, thus improving d.c. stability and reducing harmonic distortion.

5. Negative feedback is also applied from the output coupling capacitor C1, via RV1 and thermistor TH1, to the tapped load (R3 and R4) of VT1 emitter. When the oscillator is first switched on, thermistor TH1 is cold and its resistance is at a maximum. The loop gain of the oscillator is, therefore, initially high.

6. As the oscillations build up, the output amplitude and the power dissipated in TH1 increase. The resistance of TH1 falls causing an increase in the signal fed back to VT1 emitter, thus reducing the loop gain. This action continues until stable operating conditions are reached.

7. The normal output is 1·2V r.m.s. but it can be adjusted from 1·1V to 1·8V r.m.s. by means of preset potentiometer RV1.

8. The d.c. supply voltage is stabilized at -12V by Zener diode MR1 and is decoupled by filter network R15, R16, C4 and C5.

Power supply

9. The power supply required by the oscillator type 318 is -28V d.c., at approximately 10mA.

Voltage checks

10. Table 1 gives typical transistor voltages for the circuit, measured with a multimeter with respect to earth.

TABLE 1

Transistor voltages

Transistor:	Voltage measured: Collector:	Emitter:
VT1 (ASY27)	-11·5V	-1·25V
VT2 (2N1304)	-6·5V	-11·5V
VT3 (ASY27)	-11·5V	-6·5V
Across Zener diode MR1 (OAZ230):	-12V	

Performance details

11. The oscillator type 318 generates a 3kc/s ±90c/s undistorted sinewave of 1·2V r.m.s. amplitude.

Test procedure

12. Tests are carried out to ensure the correct frequency, amplitude, and shape of the output waveform. For these tests, the following equipment is required:

(1) Oscilloscope
(2) Valve voltmeter
(3) A.F. signal generator
(4) Multimeter
(5) 32-way edge-connector.

13. By means of the edge-connector, make connections to the oscillator circuit board as follows:

(1) PL1/10 - -28V d.c.
(2) PL1/1 - power earth return
(3) PL1/20 - signal output
(4) PL1/30 - signal earth return.

14. Switch the power supply on and, with the multimeter, check that the static voltages are as given in Table 1.

15. Measure the r.m.s. signal output across PL1/20 and PL1/30 with the valve voltmeter, adjusting RV1 to obtain a reading of 1·2V.

16. Connect the output of the a.f. signal generator to the A2 input of the oscilloscope. Connect the oscillator signal output to the A1 input of the oscilloscope and adjust the a.f. signal generator to give an output equal in frequency and amplitude to that of the oscillator.

17. The oscillator waveform must be an undistorted sinewave. By comparison with the waveform from the a.f. signal generator, measure the oscillator frequency. This must be 3kc/s $\pm$90c/s.

18. Adjust potentiometer RV1 and observe, on the valve voltmeter, that the amplitude of the oscillator output varies from 1·1V to 1·8V r.m.s., without noticeable distortion or change of frequency. Reset the output to 1·2V r.m.s. amplitude.

Chapter 7H

SHOT NOISE GENERATOR (FB 326)

List of Contents

List of Tables

List of Illustrations

General

1. The shot noise generator (FB 326) generates white noise of constant amplitude for injection into audio systems. The noise signal produced by this unit can thus be used to simulate background noise and static interference.

Circuit description (C54356/01)

2. Transistor VT1 is specially selected for high noise-output. The noise signals generated by VT1 are amplified by the high-gain amplifier formed by VT2 and VT3, and are fed to the automatic gain-controlled (a.g.c.) amplifier VT4, VT5 and VT6.

3. A portion of the output signal at VT6 emitter is fed back to the emitter of VT4, this portion of the output voltage appearing at VT4 emitter being determined by R16 and thermistor TH1. C7 and C8 provide d.c. blocking, but are large enough to ensure negligible phase-shift at signal frequencies. When the signal output initially builds-up, the power dissipated in TH1 increases and its resistance decreases causing an increase in negative feedback which tends to oppose the increase in output signal. The output is, therefore, maintained at a nominally constant level of approximately 2V r.m.s.

4. Resistor R14 provides a measure of bias stabilization to the a.g.c. amplifier. An increase in VT6 collector current causes a more negative potential to be applied to the emitter of VT4. This tends to reduce the emitter-base potential of VT4 and the base of VT5 is driven negative; VT5 collector rises towards 0V, and the current through VT6 is correspondingly reduced.

5. The d.c. supply to the a.g.c. amplifier is stabilized at -12V by Zener diode MR1 and capacitor C9, supplied via R19 from the -28V d.c. supply on PL1/32. Separate decoupling for VT1 and VT2, and for VT3, is provided by R7 and C3, and by R10 and C4, respectively.

6. An additional output of -12V d.c., stabilized, is available on PL1/22.

Power supply

7. The power supply required for this unit is -28V d.c. at 80mA.

Performance details

8. The unit provides a white-noise signal of approximately 2V r.m.s. amplitude, from an output impedance of less than 10 ohms. The maximum load that can be connected across the output is 220 ohms.

9. The unit also provides a stabilized d.c. output of -12V ±10 per cent from an output impedance of less than 36 ohms. The maximum loading for this output is 3 kilohms.

Voltage checks

10. Table 1 gives typical transistor voltages measured with a multimeter at various points in the circuit. All voltages are with respect to earth, and are to be taken as a guide only.

TABLE 1

Transistor voltages

Transistor:	Voltage measured:		
	Emitter:	Base:	Collector:
VT1 (V10/50A) *	-1·5V	-1·6V	-5·3V
VT2 (OC139)	-5·4V	-5·3V	-1·9V
VT3 (ACY21)	-1·8V	-1·9V	-6·5V
VT4 (ACY21)	-6·4V	-6·5V	-11·5V
VT5 (OC139)	-11·6V	-11·5V	-6·7V
VT6 (ACY21)	-6·5V	-6·7V	-11·6V

* Selected for high noise-factor.

Test procedure

11. The shot noise generator is tested for correct output signal amplitude and for the quality of the output waveform. The 112V d.c. output is checked for regulation. The test equipment required for these tests is as follows:

(1) Oscilloscope
(2) A.C. valve voltmeter
(3) Multimeter
(4) 220-ohm, 0·5-watt, ±10 per cent resistor.

12. Connect power supply (para. 7) to the shot noise generator as follows:

(1) PL1/32 - -28V d.c.
(2) PL1/11 - power earth return.

13. Connect the 220-ohm resistor between PL1/1 and PL1/11.

14. Switch on the power supply and, using the oscilloscope, observe the waveform at PL1/1. This output must consist of random noise and must not be measurably modulated with hum.

15. Connect the a.c. valve voltmeter between PL1/1 and PL1/11, and measure the r.m.s. voltage output. This must be not less than 0·5V and not greater than 2·5V.

16. With the multimeter, check the d.c. potential on PL1/22 with respect to earth. This must be between -10·8V and -13·2V.

Chapter 7I

ERASE OSCILLATOR

List of Contents

List of Illustrations

General

1. The purpose of the erase oscillator unit is to provide a high-frequency signal suitable for erasing unwanted recordings from magnetic tape. The oscillator output is a 100kc/s sinewave with low second-harmonic distortion.

Circuit description (C207805/01)

2. Transistors VT1 (ZT1702) and VT2 (ZT1702) form a tuned-collector oscillator, with positive feedback applied from secondary 1 of transformer T1 to the base of VT1. Biasing conditions are such that VT1 and VT2 operate as a pair of switches, alternately open and closed. The tuned circuit (T1 primary, C1 and C2) is thus excited into oscillation by a switched, constant-current, supply.

3. The bases of VT1 and VT2 are held at a positive level with respect to their emitters to ensure that the transistors are saturated on alternate half-cycles of oscillation; this bias is obtained from the h.t. supply via resistor R7. Capacitor C3 provides h.f. decoupling at the base of VT2; resistor R2 is included in the positive feedback loop to linearize the base current of VT1.

4. The output of the oscillator is taken from secondary 2 of T1; resistor R1 is connected across secondary 2 to prevent ringing.

Power supply

5. The erase oscillator requires a supply of +20V d.c. at approximately 0·5A. Normally, this supply is obtained from the +20V series-regulator contained in the bias oscillator unit (Chap.7J).

Performance details

6. The erase oscillator is capable of the following performance:

(1) Output amplitude - 11V peak-to-peak
(2) Output frequency - 100kc/s
(3) Output waveform - sinewave
(4) 2nd harmonic distortion - negligible.

Test procedure

7. The erase oscillator is tested by means of an oscilloscope; the required power supply of +20V d.c. is connected to PL1/U (+20V) and to PL1/AL (earth).

8. Connect the oscilloscope to PL1/A and PL1/T and observe the displayed oscillator waveform. This must be a 100 $\pm$10kc/s sinewave of 11 $\pm$1V peak-to-peak amplitude.

Chapter 7J

BIAS OSCILLATOR

List of Contents

List of Illustrations

General

1. The purpose of the bias oscillator unit is to provide a high-frequency signal, which can be superimposed on the recording current through a magnetic tape recording head to linearize the tape transfer characteristic. The oscillator output is a 100kc/s sinewave with low second-harmonic distortion. Included in the bias oscillator unit is a series-regulator circuit which supplies +20V d.c. to the bias oscillator; this voltage also forms a suitable supply for the erase oscillator (Chap. 7I).

Circuit description (C207804/01)

2. Transistors VT1 (ZT1702) and VT2 (ZT1702) form a tuned-collector oscillator with positive feedback applied from secondary 1 of transformer T1 to the base of VT1. Biasing conditions are such that VT1 and VT2 operate as a pair of switches, alternately open and closed. The tuned circuit (T1 primary, C1 and C2) is thus excited into oscillation by a switched, constant current, supply.

3. The bases of VT1 and VT2 are held at a positive level with respect to their emitters to ensure that the transistors are saturated on alternate half-cycles of oscillation; this level of bias can be varied, by means of preset potentiometer RV1, to provide adjustment of the oscillator output amplitude. Capacitor C3 provides h.f. decoupling at the base of VT2; resistor R2 is included in the positive feedback loop to linearize the base current of VT2.

4. The output of the oscillator is taken from secondary 2 of T1; resistor R1 is connected across secondary 2 to prevent ringing. Resistor R8 and capacitor C4 form a coupling network to permit the bias oscillator to be interconnected with a recording head and a recording amplifier. When such a system is used, connections must be as follows:

(1) Recording amplifier output - PL1/AC and PL1/T
(2) Recording head - PL1/W and PL1/A.

5. Transistors VT3 (ZT1702) and VT4 (2N3053), Zener diode MR1 (HS2220), and resistor R9 constitute a +20V d.c. series regulator. This +20V is supplied to the bias oscillator, and is also available via PL1/U for external connection, when required, to PL1/U of the erase oscillator (Chap.7I).

Power supply

6. The bias oscillator requires +28V d.c. at approximately 0·5A; when used in conjunction with the erase oscillator, the current requirement is approximately 1·0A.

Performance details

7. The oscillator is capable of the following performance:

(1) Output amplitude - 11V peak-to-peak
(2) Output frequency - 100kc/s
(3) Output waveform - sinewave
(4) 2nd harmonic distortion - negligible.

Test procedure

8. The following items of test equipment are required for testing the bias oscillator:

(1) Oscilloscope
(2) Multimeter.

Connect a +28V d.c. supply to PL1/L and connect the power supply earth-return to PL1/AL. Switch on the power supply and check, with the multimeter, that the voltage at VT3 emitter is +20 ±0·5V with respect to PL1/AL.

9. Connect the oscilloscope input to PL1/A and PL1/T, and adjust RV1 to obtain a 100 ±10kc/s sinewave of 11 ±1V peak-to-peak amplitude.

Chapter 7K

RECORDING LEVEL INDICATOR DRIVE AMPLIFIER

List of Contents

List of Tables

List of Illustrations

General

1. The recording level indicator drive amplifier is a two-stage current amplifier that fulfils two functions: firstly, it provides the drive current for a moving-coil recording level indicator, and secondly, it acts as a buffer between an indicator and the recording-current source. The unit is employed in tape recording systems such as the 16-channel tape recorder of the radio aids computer.

2. The components of the unit are contained in a cylindrical screening-can, connections being made by flying leads.

Circuit description (C207815/01)

3. The input to the unit is fed, via T1, C1 and R1, to the base of VT1 (OC139). Transformer T1 provides complete input-isolation; C1 prevents the base bias of VT1 being short-circuited via the secondary winding of T1.

4. The amplified signal at the collector of VT1 is directly-coupled to the base of emitter-follower transistor VT2 (OC139). D.C. and a.c. negative feedback is applied from the emitter of VT2 to the base of VT1 via T-network R3, R4, R5 and C2. This network defines the overall gain of the amplifier (approximately 14dB) and also establishes, in conjunction with R8, the d.c. base bias for VT1. The output of the unit is taken from VT2 emitter, via C3 and R9.

5. The emitters of VT1 and VT2, and the secondary of T1, are returned to a common +5·6V line, which is obtained from the +20V supply via R7 and is stabilized by Zener diode MR1 (KS36A). The +20V supply is obtained from the series-regulator circuit of VT3 (2N3053) and Zener diode MR2 (HS2220).

Power supply

6. The power supply requirement for the recording level indicator drive amplifier is +28V d.c. at 25mA.

Voltage checks

7. Typical transistor voltages, measured with respect to lead B (0V) by means of a multimeter, are given in Table 1, as a guide to fault finding.

TABLE 1

Typical transistor voltages

Transistor:	Electrode:	Voltage:
VT1 (OC139)	emitter	+5·6V ± 0·28V
VT2 (OC139)	collector	+ 20V ± 1V

Performance details

8. The unit provides constant current-amplification within a bandwidth of 100c/s to 50kc/s over a range of supply variation of +15 to +30 volts. The voltage gain of the unit is approximately 14dB.

Test procedure

9. The following test equipment is required:

(1) Oscilloscope
(2) Multimeter
(3) A.F. signal generator.

10. Connect the power supply to the unit as follows:

(1) Lead A - +28V d.c.
(2) Lead B - power supply earth.

Switch on the power supply and, with the aid of the multimeter, check that the transistor voltages are as given in Table 1.

11. Connect the a.f. signal generator output to leads C and D of the unit under test, and set the output of the signal generator to 1V peak-to-peak (as observed on the oscilloscope) at a frequency of 1kc/s. Connect the oscilloscope input to leads K (unit output) and B (earth return). The output waveform displayed on the oscilloscope must be an undistorted sinewave of approximately 5V peak-to-peak amplitude.

Chapter 7L

1020 C/S AUDIO FILTER

List of Contents

List of Tables

List of Illustrations

General

1. The 1020c/s audio filter passes a.f. signals up to and including 1020c/s and rejects a.f. signals in excess of 1020c/s. A relay is included in the circuit to ensure a sharp cut-off, in the overall frequency-response of the unit, between 1020c/s and 1300c/s. The 1020c/s audio filter can thus be used, in conjunction with a 1300c/s (high-pass) audio filter (Chap.7M), to discriminate between tones of these frequencies when they are recorded sequentially on one magnetic-tape track.

Circuit description (C208830/01)

2. The circuit comprises a voltage amplifier, VT1 (ACY21), a low-pass filter network, a variable-gain voltage amplifier, VT2 (ACY21), and a relay-driver, VT3 (ACY21). Audio frequency identification signals (idents), fed to the base of VT1, via preset gain potentiometer RV2 and capacitor C7, are amplified and passed to the filter network C2, C3, C4 and L1. The filter has a rapidly-falling frequency characteristic above approximately 1kc/s; thus the a.f. signal at the input to VT2 will have the 1300c/s content approximately 28dB down on the 1020c/s content. The gain of VT1 compensates for the insertion loss of the low-pass filter network. RV2 is adjusted to obtain an input signal amplitude of 25mV r.m.s., measured at the wiper of the potentiometer.

3. The output of VT2, the gain of which can be varied by preset potentiometer RV1, is fed to VT3 via the demodulator circuit formed by diode MR1 and a.f. filter C10 and R10. Diode MR1 conducts only on negative half-cycles of the output of VT2, and C10 and R10 remove the a.f. component of the signal. The signal at the base of VT3 thus consists of a negative voltage that remains at a steady level for the duration of the input signals up to and including 1020c/s. When the unit is used to filter coded idents, VT3 base voltage will, therefore, consist of negative-going pulses, corresponding to each burst of the ident signal.

4. VT3 conducts, when its base becomes negative, and energizes the coil of RL1. Contact set RL1/1 then operates and connects the a.f. signal from the low-pass filter network, via C6, to pin 7. In practice, the gain of VT2 is set to a level that will just enable RL1 coil to energize at an input frequency of 1100c/s; this ensures positive operation of relay RL1 at an input frequency of up to and including 1020c/s. Alternative outputs are provided by contact sets RL1/2 and /3 which, when operated, make available the unattenuated input signal.

Power supply

5. The 1020c/s audio filter requires -28V d.c. at 40mA.

Performance details

6. The unit will pass a.f. signals at frequencies up to 1100c/s.

Voltage checks

7. Typical transistor voltages, measured with respect to earth by means of a multimeter, are given in Table 1.

TABLE 1

Typical transistor voltages

Transistor:	Electrode:	Voltage:
VT1 (ACY21)	base	- 6V to - 7V
	collector	-15V to -18V
VT2 (ACY21)	base	- 6V to - 7V
	collector	-15V to -18V

Test procedure

8. The following items of test equipment are required for testing the 1020c/s audio filter unit:

(1) A.C. valve voltmeter
(2) A.F. signal generator
(3) Oscilloscope
(4) Capacitance bridge
(5) Multimeter
(6) 560-ohm, 0·25-watt resistor.

9. Connect the 560-ohm resistor between pins 7 and 1. Connect a -28V d.c. supply to pin 3 and the power supply earth-return to pin 1. Switch on the power supply and check with the multimeter that the transistor voltages are as given in Table 1.

10. Connect the a.f. signal generator output and the valve voltmeter to pin 5, using pin 1 as the earth return. Set the a.f. signal generator to give a 1100c/s sinewave. Adjust the a.f. signal generator output to obtain a reading on the valve voltmeter of 25mV.

11. Adjust the gain control RV1 until relay coil RL1 just energizes. Check by adjustment of the a.f. signal generator frequency, that RL1 coil de-energizes at frequencies exceeding 1100c/s.

12. Set the a.f. signal generator frequency to 1020c/s. Connect the oscilloscope across the 560-ohm resistor; the displayed waveform amplitude must be between 0·05V and 0·08V peak-to-peak.

Note...

1. The values of the filter network capacitors are:

   (1) C2 - 0·08μF

   (2) C3 and C4 - 0·0644μF.

2. If it becomes necessary to renew one, or more, of these capacitors, the appropriate values must be obtained, using the capacitance bridge, from combinations of preferred-value capacitors.

Chapter 7M

1300 C/S AUDIO FILTER

List of Contents

List of Tables

List of Illustrations

General

1. The 1300c/s audio filter passes a.f. signals of, or in excess of, 1300c/s and rejects a.f. signals of less than 1300c/s. A relay is included in the circuit to ensure a sharp cut-off, in the overall frequency-response of the unit, between 1300c/s and 1020c/s. The 1300c/s audio filter can thus be used, in conjunction with a 1020c/s (low-pass) audio filter (Chap.7L), to discriminate between tones of these frequencies when they are recorded sequentially on one magnetic-tape track.

Circuit description (C208831/01)

2. The circuit comprises an emitter-follower, VT1 (ACY21), a high-pass filter network, a voltage amplifier, VT2 (ACY21), a variable-gain voltage amplifier, VT3 (ACY21), and a relay-driver, VT4 (ACY21). Audio frequency identification signals (idents) fed to the base of VT1, via preset gain potentiometer RV2 and capacitor C1, are passed from the emitter of VT1 to the high-pass filter network C2, C3, L1 and C4. The filter has a rapidly-falling frequency characteristic at less than 1300c/s; thus the a.f. signal at the input to VT2 will have the 1300c/s content approximately 28dB up on the 1020c/s content. The gain of VT2 compensates for the insertion loss of the high-pass filter network. RV2 is adjusted to obtain an input signal amplitude of 25mV r.m.s., measured at the wiper of the potentiometer.

3. The output of VT2 is fed to the base of VT3, the gain of which can be varied by preset potentiometer RV1. The output of VT3 is fed to the base of VT4 via the demodulator circuit formed by diode MR1 and the a.f. filter C11 and R14. Diode MR1 conducts only on negative half-cycles of the output of VT3. The network of C11 and R14 removes the a.f. component of the signal. The signal at the base of VT3 thus consists of a negative voltage that remains at a steady level for the duration of the 1300c/s (or more) signal at the input of the unit.

4. VT4 conducts, when its base becomes negative, and energizes the coil of RL1. Contact set RL1/1 then operates and connects the a.f. signal from VT2 collector to pin 7. In practice, the gain of VT3 is set to a level that will just enable RL1 coil to energize at an input frequency of 1200c/s; this ensures positive operation of relay RL1 at an input frequency of 1300c/s. Alternative outputs are provided by contact sets RL1/2 and /3 which, when operated, make available the unattenuated input signal.

Power supply

5. The 1300c/s audio filter requires -28V d.c. at 40mA.

Performance details

6. The unit will pass a.f. signals at frequencies in excess of 1200 cycles per second.

Voltage checks

7. Typical transistor voltages, measured with respect to earth by means of a multimeter, are given in Table 1.

TABLE 1

Typical transistor voltages

Transistor:	Electrode:	Voltage:
VT1 (ACY21)	base	- 6V to - 7V
	collector	-28V
VT2 (ACY21)	base	- 6V to - 7V
	collector	-15V to -18V
VT3 (ACY21)	base	- 6V to - 7V
	collector	-15V to -18V

Test procedure

8. The following items of test equipment are required for testing the 1300c/s audio filter unit:

(1) A.C. valve voltmeter
(2) A.F. signal generator
(3) Oscilloscope
(4) Capacitance bridge
(5) Multimeter
(6) 560-ohm, 0·25-watt resistor.

9. Connect the 560-ohm resistor between pins 7 and 1. Connect a -28V d.c. supply to pin 3 and the power supply earth-return to pin 1. Switch on the power supply and check with the multimeter that the transistor voltages are as given in Table 1.

10. Connect the a.f. signal generator output to pin 5, using pin 1 as the earth return, and connect pin 2 to pin 1. Connect the valve voltmeter between the wiper of RV2 and pin 1. Set the a.f. signal generator to give a 1200c/s sinewave, centralize the wiper of RV2 and adjust the a.f. signal generator output to obtain a reading on the valve voltmeter of 25mV.

11. Adjust the gain control RV1 until relay coil RL1 just energizes. Check, by adjustment of the a.f. signal generator frequency, that RL1 coil de-energizes at frequencies of less than 1200c/s.

12. Set the a.f. signal generator frequency to 1300c/s. Connect the oscilloscope across the 560-ohm resistor; the displayed waveform amplitude must be between 0·05V and 0·08V peak-to-peak.

Note...

1. The values of the filter network capacitors are:
   (1) C2 and C3 - 0·199μF
   (2) C4 - 0·17μF.
2. Should it become necessary to renew one, or more, of these capacitors, the appropriate values must be obtained, using the capacitance bridge, from combinations of preferred-value capacitors.

Chapter 8A

AIR NOISE UNIT TYPE 307

List of Contents

List of Tables

List of Illustrations

General

1. The aircraft air noise unit, type 307, constitutes a common unit which generates the basic air and engine noise signals for the flight simulator noise system. These air noise signals are filtered and shaped in the engine noise units where further mixing of noise signals is made. The outputs of the respective engine noise units are fed either directly, or via mixer units, to the loudspeaker units which reproduce the audio noises in the cockpit section of the fuselage.

2. The following noise signals are produced in the air noise unit:

(1) The basic white noise signal which is suitably modified to provide:
  (a) Jet-roar output signal
  (b) Aircraft profile air noise signal which includes the undercarriage profile air noise and the taxi rumble noise components
(2) Turbine-whine signal from a separate 20kc/s oscillator.

In addition to the noise signal circuits, the air noise unit contains a -20V voltage stabilizer which supplies the transistorized circuits of the aircraft noise system with the exception of the loudspeaker units which are fed with the general -27V supply.

Circuit description (C52954/01)

3. The circuits of the air noise unit are supplied with -27V; this -27V supply is stabilized by a standard voltage regulator circuit to a -20V regulated output to prevent any frequency variations of the audio noises produced.

-20V voltage stabilizer

4. The -27V supply is applied via fuse FS1 to the voltage stabilizer circuit which consists of series-connected transistor VT11 and error-amplifier transistor VT12. The reference voltage, nominally 9·1V, produced at the junction of resistor R17 and Zener diode MR3, establishes the potential of the emitter of VT12. The base potential is supplied from the wiper of RV11 which, together with R15 and R16, forms a potential-divider across the stabilized output. The ripple and voltage error content of the output line is also supplied via RV11 to the base of VT12 which inverts this signal and feeds the base of VT11. A time constant of 0·8 second (R14, C9) is included in the base circuit of VT11 to provide damping of transient disturbances on the stabilized line. The stabilized output, which is smoothed by capacitor C10 and is preset to -20V d.c. by potentiometer RV11, supplies the transistor circuits of the air noise unit and, via PL1/7, the circuits of the other units of the noise system.

5. The -27V supply is fed, via the four operated contact sets of relay RL3, to PL1/6, /8, /10 and /12 and, externally, to the loudspeaker units. Relay RL3 is operated when the energizing voltage via PL1/23 is switched on at a specified minimum engine speed (nominally above 8·25% indicated); the appropriate mixture of noises then becomes audible via the loudspeaker units.

White noise generator

6. The white noise generator consists of a specially selected transistor VT1 which is operated with an open-circuited base; the leakage current of the transistor produces a relatively high noise output across the load resistor R1. This noise signal is amplified by the second transistor stage (VT2) which includes a preset noise-level potentiometer RV1 in its collector circuit. The amplified noise signal is applied to emitter-follower VT3 for distribution to the filtering circuit. The common low-pass filter consists of resistor R8 and capacitor C4 from which the basic jet-roar signal is taken, via PL1/18, to the individual engine noise units. The other circuits which receive the white noise signal from the this filter are:

(1) The aircraft profile air noise circuit (para. 8)
(2) The undercarriage profile air noise circuit (para. 10)
(3) The taxi rumble noise circuit (para. 11).

Turbine whine generator

7. The circuit of transistor VT4 is arranged as a phase-shift oscillator operating at a frequency of 20kc/s. The positive feedback from the collector to the emitter of VT4 is obtained from the junction of capacitors C5 and C6 which, together with preset potentiometer RV2, establish the operating frequency. Current through the transistor is set by the base voltage obtained at the junction of resistors R9 and R10. The 20kc/s output is available at the wiper of preset potentiometer RV3 which controls the amplitude of the output, delivered via PL1/20 as the basic turbine whine noise, to the individual engine noise units.

Aircraft profile air noise circuit

8. The jet roar noise (white noise) signal from emitter-follower VT3 (para. 6) is applied to the variable-gain circuit of transistor VT5 which includes suitable filters to shape the basic white noise into the representative air noise due to the aircraft profile. The resulting noise signal amplitude is made proportional to the aircraft speed signal produced in the flight computer.

9. The filtered white noise signal, fed via preset amplitude potentiometer RV4 and capacitor C13, is rectified by diode MR1 and applied to the base of transistor VT5. The transistor current is set by resistors R19 and R20, and by variable positive voltage from an external speed potentiometer via PL1/22, resistor R38 and preset potentiometer RV10. The output of VT5 is attenuated at low frequencies by C15, and is passed via capacitor C14 and scaling resistor R23 to PL1/16 for mixing with the undercarriage noises, as applicable. Potentiometer RV10 is set to adjust the aircraft profile noise to zero amplitude at a bias voltage, from the speed potentiometer, equal to +30V.

Undercarriage profile air noise circuit

10. The white noise signal from VT3 (para.6) is supplied via RV5 and C17 to a two-stage circuit, VT6 and VT7. The circuit of VT6 is an amplifying stage which receives its h.t. voltage via contact set RL1/1; relay RL1 is operated by a +27V supply from the landing gear system when the undercarriage is lowered. Resistor R29 and preset potentiometer RV6 decrease the h.t. supply to VT6 to a convenient voltage when connected to the VT6 circuit, and provide a resistive charging path for capacitor C16, C16 and preset potentiometers RV6 and RV7 provide a progressive build-up and decay, respectively, of the h.t. voltage depending on the state of contact set RL1/1, and thus the undercarriage profile air noise builds-up or fades as the undercarriage is extended or retracted. The signal from VT6 collector is fed, via C18, to diode MR2 for negative clipping, and then to the base of variable-gain stage of transistor VT7. The gain of this stage is varied with the aircraft speed potentiometer the wiper of which is connected, via PL1/3, resistor R46 and preset potentiometer RV12, to the base of VT7. Capacitor C28 delays the increase or decrease of the biasing voltage from the speed potentiometer. The output circuit of VT7 includes an h.f. by-pass capacitor C19, coupling capacitor C20 and scaling resistor R34.

Taxi rumble noise circuit

11. The white noise signal from VT3 (para.6) has all components above 8c/s removed by low-pass filter network C21 R35, C22, and the resultant signal is applied to the base of transistor VT8; the amplified signal from the collector of VT8 is fed to a similar amplifying stage of VT9 and to a variable-gain amplifier stage of VT10. The positive biasing voltage is obtained from an aircraft speed potentiometer which supplies the base of VT 10 via R47 and RV9, and which also controls the undercarriage profile air noise circuit of VT7 (para.10). When the simulated aircraft is airborne and the undercarriage is retracted, contact set RL2/1 is released and the undercarriage taxi rumble signal, from VT10, is short-circuited to earth. When the aircraft touches-down, a signal from the height and touchdown

system energizes the coil of RL2; contact set RL2/1 is operated and the undercarriage taxi rumble signal is fed, via scaling resistor R53 and preset potentiometer RV8, to PL1/16, and externally, to the individual engine noise units.

12. Contact set RL2/2 (not used) is connected between earth and PL1/5 which is not connected externally.

Power supply requirements

13. The aircraft air noise unit requires a general supply of -27V at 750mA (maximum) which provides the unstabilized supply to the internal -20V stabilizer and is also used for the operation of the three relays.

Performance details

14. The aircraft air noise unit provides the following outputs:

(1) -20V stabilized output at 500mA
(2) Jet-roar output at 0·3V peak-to-peak
(3) 20kc/s turbine-whine output at 1·5V peak-to-peak
(4) Aircraft profile air noise output at 0·3V peak-to-peak
(5) Undercarriage profile air noise output at 1·0V peak-to-peak
(6) Undercarriage taxi rumble at 0·8V peak-to-peak.

Voltage checks

15. The typical transistor voltages listed in Table 1 are measured, using a multimeter, with respect to audio earth (PL1/11). A tolerance of ±30 per cent (maximum) may be allowed to cover any permissible transistor characteristics spread.

TABLE 1

Transistor voltages

	Voltage measured:		
	Emitter:	Base:	Collector:
VT1 (selected type)	0V	-	-14·0V
VT2 (OC75)	- 1·6V	- 1·7V	- 7·0V
VT3 (OC75)	-14·5V	-14·7V	-20·0V
VT4 (OC75)	-10·1V	-10·2V	-12·5V
VT5 (OC75)	- 2·4V	- 2·5V	-13·5V
VT6 (OC75)	Voltages depend on the setting of RV6		
VT7 (OC75	- 2·0V	- 2·1V	-14·0V
VT8 (OC75)	- 1·6V	- 1·7V	- 5·7V
VT9 (OC75)	- 1·6V	- 1·7V	- 5·7V
VT10 (OC75)	- 3·0V	- 3·1V	-12·0V
VT11 (2N257)	-20·0V	-20·2V	-27·0V
VT12 (GET 116)	- 9·1V	- 9·3V	-20·2V

Test procedure

16. The following test procedure consists of adjustment of the output voltage of the voltage stabilizer, frequency checks and output amplitude adjustments of the noise generators. The following test equipment is required:

(1) Multimeter
(2) Oscilloscope
(3) A.F. signal generator
(4) Three single-pole switches
(5) One 220-pF, ±10 per cent capacitor
(6) One 68-kilohm, 0·25-watt, ±10 per cent resistor
(7) One 150-ohm, 3-watt, ±5 per cent resistor
(8) Two 2·5-kilohm potentiometers
(9) Stopwatch.

17. Check that the fuse FS1 (0·5A) is fitted and set all preset potentiometers (on the unit) as follows:

(1) RV1, RV8 and RV11 - fully counter-clockwise
(2) RV2, RV7, RV9, RV10 and RV12 - to mid-position
(3) RV3, RV4, RV5 and RV6 - fully clockwise.

18. Connect the unit, as shown in the test circuit (Fig. 1). Rotate the wipers of the 2·5-kilohm potentiometers (in the test circuit) to the audio-earth end of travel. Set the three switches (in the test circuit) to the off position. Connect the required power supplies to the unit under test and to the test circuit (+50V to the test circuit potentiometers).

Voltage stabilizer

19. Switch on the power supplies and measure, with the multimeter, the -20V output of the voltage stabilizer, PL1/7; adjust RV11 to obtain exactly -20V on the multimeter Allow at least 5 minutes warming-up time before rechecking the -20V stabilized output; re-adjust RV11, if necessary.

Note...
The maximum ambient operating temperature of the unit is 60°C.

20. Check that the transistor voltages are as stated in Table 1.

20kc/s oscillator

21. Set the a.f. signal generator to give a 20kc/s output and connect this output to one beam of the oscilloscope. Connect the output of the 20kc/s oscillator, PL1/20, to the second beam of the oscilloscope. Compare at least six cycles of the waveforms and adjust RV2, if required, to obtain a turbine-whine output of exactly 20kc/s.

22. Check the turbine-whine output amplitude (on the oscilloscope). With RV3 wiper turned fully clockwise, the amplitude (peak-to-peak) must be at least 12·5V; when the wiper is fully counter-clockwise, the amplitude must be approximately 1V. Set RV3 to obtain a peak-to-peak output of 1·5V. Disconnect the oscilloscope.

White noise generator

23. Connect the oscilloscope between PL1/18 and earth, PL1/11, and set potentiometer RV1 (on the unit) to obtain a peak-to-peak noise output (on the oscilloscope) of 0·3V. Disconnect the oscilloscope.

Note...
If the noise level is below the specified 0·3V output at the fully clockwise position of RV1 (maximum output), it is necessary to reselect VT1.

Aircraft profile noise stage

24. Connect the oscilloscope between VT5 collector and earth, PL1/11. With RV10 wiper in the mid-position (para. 17), adjust RV4 to obtain a 0·3V (peak-to-peak) air noise output on the oscilloscope. Rotate RV2 (in the test circuit) to obtain (on the multimeter) a d.c. output, at the wiper of this potentiometer, of +30V. Adjust RV10 (on the unit) so that the profile noise output is reduced to zero volt amplitude. Check that the profile noise output reaches maximum amplitude, when RV2 (in the test circuit) is set for a d.c. output of approximately +23V. Return the wiper of RV2 to the audio earth position and disconnect the oscilloscope.

Undercarriage profile air noise stage

25. Connect the oscilloscope between VT7 collector and earth, PL1/11. Operate the "undercarriage down" slave relay RL1 by means of switch S1 (in the test circuit), and observe the waveform on the oscilloscope. The output waveform should rise to maximum amplitude after a delay of approximately one minute, due to the charging action of capacitor C16. Release the "undercarriage down" relay RL1 and adjust the wiper of RV6 to a position at which the noise output increases to 70 per cent of its maximum amplitude within eight seconds after the operation of RL1.

26. Operate RL1 for 30 seconds and adjust RV7 so that the noise output decreases to 20 per cent of its maximum amplitude within five seconds after the release of RL1.

27. Operate RL1 and adjust RV1 (in the test circuit) so that a d.c. voltage of +20V is obtained at its wiper. Adjust RV12 (on the unit) to a setting at which the undercarriage noise signal is reduced to zero volt amplitude. Check that the undercarriage noise signal attains maximum amplitude when RV1 (in the test circuit) is set for a d.c. output of +16V. Return the wiper of RV1 (in the test circuit) to the audio earth position. With the oscilloscope, measure the undercarriage noise signal; the peak-to-peak value must be approximately 1·0V.

Note...

Potentiometer RV5 may require adjustment if the specified test results are not easily obtained. If RV5 is reset, the procedure specified in para. 25 to 27 inclusive must be repeated.

28. Release the "undercarriage down" relay RL1. Disconnect the oscilloscope.

Taxi rumble stage

29. Connect the oscilloscope across resistor R52. Operate "touchdown" relay RL2 by means of switch S2 (in the test circuit) and measure (on the oscilloscope) the output of VT10. Check that the amplitude of the taxi rumble signal is approximately 0·8V (peak-to-peak). Adjust RV1 (in the test circuit) so that a d.c. voltage of +25V d.c. is obtained on its wiper. Adjust RV9 (on the unit) to a setting at which the taxi rumble signal is reduced to zero volt amplitude. Check that the taxi rumble signal attains maximum amplitude when RV1 (in the test circuit) is set for a d.c. output of +18V. Return the wiper of RV1 to the audio earth position. Release the "touchdown" relay RL12 and check that the taxi rumble signal level is reduced to zero volts. Set the wiper of RV8 to the fully clockwise position. Disconnect the oscilloscope.

Operation of RL3

30. Connect the multimeter between audio power supply output at PL1/6 and earth, PL1/11. Check that the multimeter reads -27V d.c. when the audio supply relay RL3 is operated by means of switch S3 (in the test circuit). Ensure that the multimeter reads 0V when RL3 is released.

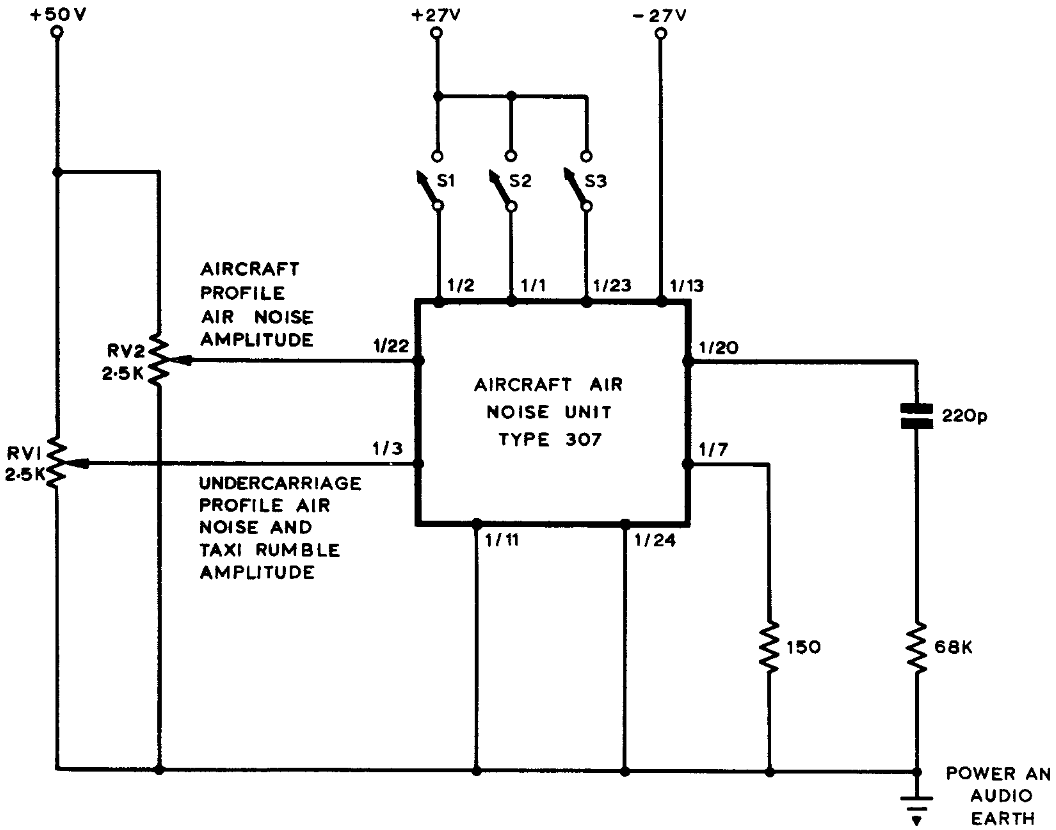


Fig.1 Aircraft air noise unit – test circuit

Chapter 8B

ENGINE NOISE UNIT TYPE 308

List of Contents

List of Tables

List of Illustrations

General

1. The flight simulator noise system contains the required number of identical engine noise units which are fed with the basic noises produced in the air noise unit and which provide the required noise outputs related to the speed of the respective engines or to aircraft speed, as applicable.

2. The engine noise units are supplied with the following noise signals from the common air noise unit:

(1) Jet roar
(2) Aircraft profile air noise which includes the undercarriage profile air noise and the taxi rumble
(3) Turbine whine.

3. The engine noise unit circuits provide the following signals:

(1) Jet roar signal
(2) Engine turbine starting noise signal
(3) Propeller noise signal
(4) Frequency-controlled turbine whine signal.

Note...
In certain applications the turbine start and propeller noise signals may not be used.

The component signals are applied to a common mixing stage which provides one output fed to the aircraft noise mixer units or directly to the corresponding loudspeaker unit of the noise system.

Circuit description (C59253/01)

4. The circuits of the engine noise unit are supplied with the -20V stabilized output from the voltage regulator unit in the air noise unit in order to achieve stability of the audio outputs produced in this unit.

Jet roar and turbine start noise circuits

5. The white noise from the air noise unit is applied to two parallel circuits of transistors VT1 and VT2. The VT1 stage provides amplitude control, that is proportional to aircraft and engine speeds, of the jet roar signal; the VT2 circuit is switched on by contact sets of the "engine start" slave relay and produces the characteristic jet-engine turbine starting noise.

6. The jet roar signal for the jet roar stage of VT1 is obtained from the wiper of RV1 which is preset to a specified amplitude level during tests. This signal is rectified by diode MR1 and applied to a variable-gain stage, VT1. VT1 receives a fixed bias from the junction of resistors R2 and R3, and a variable bias from two independent sources:

(1) from a speed potentiometer (via PL1/22, R38 and RV9) which is preset on test to provide a maximum output of VT1 at zero volts bias from its wiper (speed equal to zero).
(2) from an engine speed potentiometer (via PL1/5, R45, R39 and RV13) which is preset during test to obtain a maximum output of VT1 at zero volt bias from its wiper (engine speed at maximum revolutions). The engine speed potentiometer also supplies the control voltage to the propeller noise amplifier VT4 (para.9), and to the turbine noise mixer VT7 (para.12).

7. The signal from collector of VT1 is fed via C4 and scaling resistor R6 to the common mixer stage of VT8 (para.13).

8. The engine turbine start noise stage of VT2 provides the characteristic initial turbine noise when the engine is started. The jet roar input via PL1/20 is set to a specified amplitude by RV2, and is applied via C5 to the base of VT2. Before the engine is started, VT2 collector is disconnected from the h.t. line by contact set RL1/1 of the "engine start" slave relay RL1 which is operated when the aircraft is groundborne and the engines are started. Operated contact set RL1/1 disconnects the charged capacitor C8 from the h.t. feed resistor R11 and the discharge current of C8 provides a decaying h.t. supply to VT2; simultaneously, operated contact set RL1/2 connects the output of VT2, via scaling resistor R12, to the common mixer stage of VT8. Potentiometer RV3 controls the discharge rate of capacitor C8. Operated contact set RL1/3 supplies an engine starting signal to the external circuit via PL1/19.

Propeller noise generator circuit

9. The propeller noise is produced by the variable-frequency stage of blocking oscillator VT3 that is set to a basic frequency by potentiometer RV4. The base voltage of VT3, and thus the output frequency, is varied between 15 and 100c/s by an engine speed potentiometer, via PL1/7, which also provides variable bias, proportional to the engine speed, to the separate turbine noise generator circuit of VT5 (para.11). The sawtooth output of VT3 is fed, via C10 and R16, to the variable-gain amplifier stage of VT4 which obtains its control bias voltage, via preset potentiometer RV11, R19, R45 and PL1/5, from an engine speed potentiometer. The amplitude of the amplified propeller noise signal is preset by RV5, and the signal

is fed, via PL1/11, an external link to PL1/13, and scaling resistor R21, to the common mixing stage of VT8. When pure-jet engine noises are simulated, the external link between PL1/11 and PL1/13 is not fitted.

Turbine whine circuits

10. The turbine whine is obtained by mixing a 20kc/s sinewave output of the air noise unit with a sawtooth output of blocking-oscillator circuit of VT5 which provides a variable-frequency output related to the engine speed. The two outputs are mixed and the beat-frequency output is amplified by VT6 and VT7 at a level related to the engine speed.

11. The circuit of blocking oscillator VT5 is similar to that of the propeller noise oscillator VT3 (para.9), except for the values of the associated components which are selected to set the basic sawtooth frequency to 20kc/s. Fine adjustments of this output frequency are made by preset potentiometer RV6 at a bias voltage from an engine speed potentiometer (para.9) of zero volts. The upper limit of the sawtooth frequency is set by RV10 to 25kc/s at a bias voltage of -50V.

12. The output of VT5 is fed, via C15, to the base of mixer stage of emitter-follower VT6 which is also fed with the sinewave output of the air noise unit via C24 and R43. The emitter output of VT6 is shaped by filter network R30, R31, R33, C18 and C19, before being amplified by VT7 to a level set by RV7. The gain of this stage is governed by the varibale base bias of VT7, the current of which varies in proportion to the bias voltage supplied via RV12 and R32 from an engine speed potentiometer (para.6 (2)). Additional biasing can be applied from another external control circuit via PL1/9, if required. The output of VT7 is fed, via C20 and R37, to the common mixing stage of VT8.

Common engine noise mixing stage

13. The engine noise unit provides one output, at PL1/2, of the mixed component noise signals which are summed at the base of VT8 and which consist of the following:

(1) Jet roar signal via R6
(2) Turbine starting noise signal via R12
(3) Propeller noise signal via R21
(4) Turbine whine via R37
(5) Aircraft profile noise signal via R44 from the air noise unit.

Note...
In certain applications the turbine start and propeller noise signals may not be used.

Power supply requirements

14. The engine noise unit requires a stabilized supply of -20V d.c. at 28mA (maximum), and -27V general d.c. supply at 22mA for the operation of relay RL1.

Performance details

15. The engine noise unit provides one common output which contains all the component air and engine noise signals at frequencies and amplitudes related to the simulated aircraft conditions, specific amplitude and frequency values cannot, therefore, be given.

Voltage checks

16. The typical transistor voltages listed in Table 1 are measured (with a multimeter) with respect to audio earth (PL1/18). A tolerance of 30 per cent (maximum) may be allowed to cover any permissible transistor characteristics spread.

TABLE 1

Transistor voltages

Transistor:	Voltage measured:		
	Emitter:	Base:	Collector:
VT1 (OC75)	- 1·9V	-2·0V	-15·0V
VT4 (OC75)	- 1·6V	-1·7V	-13·0V
VT6 (OC75)	-10·5V	-9·5V	-20·0V
VT7 (OC75)	- 2·9V	-3·0V	- 9·0V
VT8 (OC75)	- 1·5V	-1·6V	-11·5V
Junction of R25 and R26		-9·5V	

Test procedure

17. The following test procedure consists of frequency checks, amplitude adjustments and variable bias checks of the noise generating and amplifying stages. The following test equipment is required:

(1) Multimeter
(2) Oscilloscope
(3) A.F. signal generator
(4) One single-pole switch
(5) Three 5-kilohm potentiometers
(6) One 820-kilohm, 0·25-watt, ±10 per cent resistor
(7) Resistors, 0·25-watt, ±10 per cent, for selection of R23 (average values 150 to 180 kilohms)
(8) Stopwatch.

18. Set the preset potentiometers (on the unit) as follows:

(1) RV1, RV2, RV3, RV5, RV7 and RV8 - fully clockwise
(2) RV4, RV6, RV9, RV10, RV11, RV12 and RV13 - to mid-position.

19. Connect the unit as shown in the test circuit (Fig. 1). Rotate the wipers of the three 5-kilohm potentiometers (in the test circuit) to the audio-earth end of travel. Set switch S1 (in the test circuit) to the off position. Connect the required power to the unit under test, and to the test circuit (+50V and -50V to the test circuit potentiometers).

20. Switch on the power supplies and allow at least 5 minutes warming-up time.

Note...
The maximum ambient operating temperature of the unit is 60°C.

21. With the multimeter check that the transistor voltages are as stated in Table 1.

Jet roar and turbine start noise stages

22. Connect the a.f. signal generator output to PL1/20 and apply 1kc/s sinewave of approximately 0·5V r.m.s. level to the jet roar and turbine-start noise circuits. Connect the oscilloscope between the collector of VT1 and audio earth. Rotate the wiper of RV1 (in the test circuit) to obtain +16V d.c. output from its wiper. Adjust RV13 (on the unit) so that the output of VT1 is reduced to 0V. Rotate the wiper of RV1 (in the test circuit) towards the audio-earth end of travel and ensure that the maximum VT1 output occurs at 0V d.c. bias, which is equivalent to maximum engine speed; leave RV1 (in the test circuit) set for this condition.

23. Rotate the wiper of RV2 (in the test circuit) to obtain +17V d.c. output from the wiper. Adjust RV9 (on the unit) so that the output of VT1 is reduced to 0V. Rotate the wiper of RV2 (in the test circuit) towards the audio-earth end of travel and ensure that the maximum VT1 output occurs at 0V d.c. bias which is obtained when aircraft speed is equal to zero. Disconnect the oscilloscope.

24. With the a.f. signal generator connected and set as in para.22, connect the oscilloscope input to the junction of R12 and pin 12 of contact set RL1/2. Energize the coil of the "engine start" slave relay RL1 by means of switch S1 (in the test circuit). Adjust RV3 (on the unit) so that the output of VT2 is reduced to 20 per cent of its initial maximum value within 7 seconds. Disconnect the oscilloscope.

Propeller noise stage

25. Connect the a.f. signal generator, set in turn to the sinewave outputs detailed in Table 2, to one beam of the oscilloscope; compare the frequency of this output with the sawtooth output of the propeller noise oscillator at the green terminal of T1, to which the second beam of the oscilloscope is connected, at the specified VT3 bias voltages (Table 2) supplied from the wiper of RV2 (in the test circuit).

Note...
Comparison of the frequencies is carried out with the screening can of transformer T1 removed.

TABLE 2

Propeller noise oscillator frequency check

RV4 (on the unit) wiper position:	Bias voltage from wiper of RV2 (in the test circuit):		
	0V		-50V
Fully clockwise	45c/s	to	100c/s
Fully counter-clockwise	15c/s	to	70c/s

26. Set RV4 (on the unit) to obtain an output of 90c/s at -50V bias from the wiper of RV2 (in the test circuit); reset RV2 for 0V bias. Potentiometer RV11 (on the unit), by which the variable bias to VT4 is set, is adjusted after the setting of the turbine whine stages is completed (para.31).

Turbine whine stages

27. With the a.f. signal generator, set to a 20kc/s sinewave output and connected to one beam of the oscilloscope, compare the sawtooth output of the turbine variable-frequency oscillator at the green terminal of transformer T2, to which the second beam of the oscilloscope is connected via an 820-kilohm resistor.

Note...

Comparison of the frequencies is carried out with the screening can of transformer T2 removed. The 820-kilohm resistor must be inserted between the end of the oscilloscope lead and the green terminal of T2.

28. With RV6 (on the unit) set to mid-position (para.18), select resistor R23 (starting value 150 to 180 kilohms) to obtain a sawtooth output of approximately 20kc/s. Compare at least 6 cycles of the two waveforms and adjust RV6 (on the unit) to a setting at which the output of T2 is exactly 20kc/s.

29. Set the a.f. signal generator output frequency to 25kc/s. Adjust RV3 (in the test circuit) to obtain 150V at its wiper. Adjust RV10 (on the unit) until the two waveforms (on the oscilloscope) are of identical frequency; compare at least 6 full cycles of the waveform for accurate results.

30. Set the a.f. signal generator to 20kc/s and connect its output to the turbine mixer input, PL1/3. Connect the oscilloscope to the collector of VT7. Adjust RV1 (in the test circuit) to obtain +35V d.c. at its wiper. Adjust RV12 (on the unit) so that the 20kc/s mixer output is reduced to 0V. Re-adjust the position of the wiper of RV1 (in the test circuit) towards the audio-earth end of travel and observe the mixer output. Ensure that the maximum signal amplitude is obtained at a bias of +25V d.c. from RV1 (in the test circuit). Leave RV1 set for the +25V d.c. output. Disconnect the oscilloscope and a.f. signal generator.

Final adjustment of propeller noise output

31. Connect the oscilloscope to the propeller noise amplifier output, PL1/11. Ensure that RV1 (in the test circuit) is set for an output of +25V d.c. Adjust RV11 (on the unit) to obtain a 0V propeller noise amplifier output. Rotate the wiper of RV1 (in the test circuit) towards the audio-earth end of travel. Check that the propeller noise output reaches a maximum amplitude at a bias of approximately +10V d.c. from RV1 (in the test circuit). Disconnect the oscilloscope.

Noise output stage

32. Connect the oscilloscope between the audio noise output, PL1/2, and audio earth, PL1/18. By observing the propeller noise and turbine whine outputs, check the operation of RV8 (on the unit). Reset RV8 to the centre position. Disconnect the oscilloscope.

Current consumption test

33. Set the multimeter to 100mA range and check the total current consumption of the unit by connecting the multimeter between PL1/1 and the -20V supply. Check that the current consumption is approximately as follows:

(1) With the wipers of RV1, RV2 and RV3 at earth potential - 28mA
(2) With the wipers of RV1, RV2 and RV3 at the 50V potentials - 21mA.

34. Disconnect all test equipment and power supplies.

Diode MR5 test

35. With the multimeter, connected between PL1/24 and pin 10 of contact set RL1/1, measure the forward and reverse resistance of diode MR5. The typical ohmic values are as follows:

(1) Forward resistance - 500 ohms
(2) Reverse resistance - 300 kilohms.

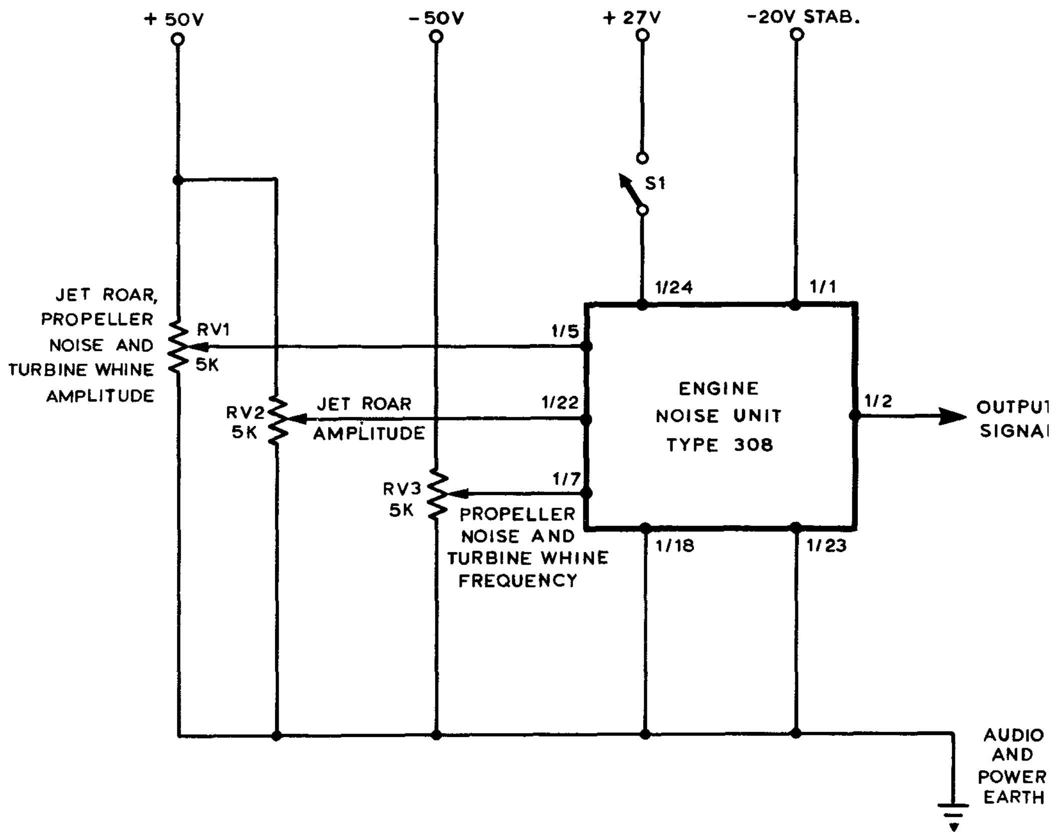


Fig. 1 Engine noise unit – test circuit

Chapter 8C

AIRCRAFT NOISE MIXER UNIT

List of Contents

List of Tables

List of Illustrations

General

1. The aircraft noise mixer unit contains two identical, transistorized, mixing stages, each being capable of receiving up to four audio inputs. These inputs are supplied normally from the engine noise units; the common output, from one section of the mixer unit, is fed to the loudspeaker units of the noise system. The mixer unit power supply consists of -20V which is obtained from the -20V stabilizer in the aircraft noise unit.

Circuit description (C218106/01)

2. Section 1 of the mixer unit consists of transistor VT1 (OC83) and the associated buffer-amplifier circuit. Provision is made for four possible inputs which are mixed via the respective mixing resistors R1, R2, R3 and R4. C1 blocks the d.c. signal component. The mixed input is applied via C1 to the base of VT1 which receives a fixed bias from the junction of resistors R5 and R7, and a.c. and d.c. negative feedback, via R6, from the collector. The collector output signal is fed via PL1/8 to the external circuits.

3. The circuit of section 2 is similar except for component references.

Power supply

4. The mixer unit requires a stabilized supply of -20V d.c. at 20mA.

Test procedure

5. Tests of the mixer unit consist of functional tests of each mixer section. The following test equipment is required:

(1) Multimeter
(2) Oscilloscope
(3) A.F. signal generator.

6. Connect the required power supplies to the unit and allow 2 to 3 minutes for the unit to stabilize.

7. Connect the a.f. signal generator to input No.1, i.e., between PL1/2 and PL1/6. Connect the oscilloscope across the a.f. signal generator output and set the a.f. signal generator output to 300c/s at 1V peak-to-peak. Remove the oscilloscope input from PL1/2 and connect it to the output of section 1, PL1/8. Check that the output waveform is undistorted and that the amplitude is 1V peak-to-peak.

8. Carry out similar tests for all inputs of section 1 and 2, in turn, as detailed in Table 1.

TABLE 1

Mixer unit - test connections

A.F. signal generator connection:	Oscilloscope connections:
PL1/2	PL1/8
PL1/3	PL1/8
PL1/4	PL1/8
PL1/5	PL1/8
PL1/20	PL1/17
PL1/21	PL1/17
PL1/22	PL1/17
PL1/23	PL1/17

Chapter 8D

LOUDSPEAKER UNIT

List of Contents

List of Tables

List of Illustrations

General

1. The circuit of the loudspeaker unit comprises the following:

(1) Phase-splitter driver stage
(2) 5-watt push-pull output stage
(3) Loudspeaker.

The circuit components are mounted on a printed circuit board to which are attached the heat sinks of the phase-splitter and output stage transistors.

Circuit description (D97604/01)

2. The phase-splitter stage of transistor VT3 is of the split-load type, and is R-C coupled to the output stage. R11 and C4 provide power supply decoupling for VT3.

3. The input to the phase-splitter, via C1, taken from one section of the aircraft noise mixer unit (Chap.8C), consists of audio signals covering a wide frequency range Adequate h.f. response, necessary for reproduction of, for example, turbine whine, is inherent in the circuit used. Good l.f. response, required for taxi rumble noise, is ensured by large coupling-capacitance values of C3 and C4.

4. A biasing control, RV2, provides the means of adjustment of VT3 base current to cover any spread in transistor characteristics, and to balance the amplitudes of the anti-phase signals supplied by this stage.

5. VT1 and VT2 form a class B push-pull power amplifier output stage; the maximum power output is 5 watts into 15 ohms. Potentiometer RV1 is provided for adjustment of the standing currents through VT1 and VT2. Diodes MR1 and MR2 prevent the bases of VT1 and VT2 becoming positive due to charge build-up on C2 and C3. If this build-up occurred, the output transistors could be biased back to class C conditions, resulting in severe distortion.

6. Negative feedback is applied from collector to base of VT1 and VT2, via resistors R9 and R10. This feedback provides a measure of d.c. bias stabilization, and lowers the output impedance.

7. The loudspeaker, LS1, is rated at 10 watts and has a 15 ohm, centre-tapped, speech coil which is connected directly to the collectors of VT1 and VT2. The negative power supply to VT1 and VT2 is connected to the centre-tap of LS1, via the decoupling network of R12 and C5.

Power supplies

8. The power supply required by the loudspeaker unit is:

-27V d.c. at 1·0A.

Performance details

9. The loudspeaker unit is capable of reproducing all the simulated aircraft noises generated by the noise system, with a maximum undistorted power output of 5 watts.

Voltage checks

10. Typical transistor voltages are listed in Table 1. The voltages are measured, using a multimeter, with respect to audio earth (PL1/2) and with no input applied to PL1/4.

Note...
Collector voltages must be measured at the collector connections and not at the heat sinks.

TABLE 1

Transistor voltages

Transistor:	Electrode:	Voltage measured:
VT1, VT2 (2N257)	collector	-19·5V
VT3 (2N257)	emitter	-6·0V
	base	-6·2V
	collector	-16·0V

The voltage at the centre-tap of LS1 speech coil is approximately -21V. The voltages measured may differ from those quoted above by ±20 per cent due to transistor characteristics spread.

Test procedure

11. Tests on the loudspeaker unit include setting-up static d.c. potentials and balancing the phase-splitter outputs at 1kc/s. The equipment required for these tests is as follows:

(1) A.F. signal generator
(2) Oscilloscope
(3) Multimeter.

Note...
If it is difficult to adjust the a.f. signal generator output for these tests, series resistors of suitable values can be inserted between the a.f. signal generator output and PL1/4.

12. Connect the power supplies to the loudspeaker unit as follows:

(1) PL1/1 - -27V d.c. at 1A
(2) PL1/2 - audio and power earth return.

13. Adjust RV1 to obtain -21V, on the multimeter, at the centre tap of LS1 and check that the collectors of VT1 and VT2 are at -19·5V.

14. Adjust RV2 to obtain the static voltages given in Table 1.

15. Allow a 5-minute warming-up period before carrying out further tests.

16. Repeat the procedures detailed in para. 13 and 14.

17. Apply a 1kc/s sinewave from the a.f. signal generator output to the signal input, PL1/4, and audio earth, PL1/2.

18. Using the oscilloscope, observe the waveforms at VT3 collector and emitter in turn, adjusting the a.f. signal generator output until squaring of the waveforms at VT3 collector and emitter just occurs. Adjust RV2 to obtain an equal degree of squaring at the emitter and collector.

19. Decrease the input until squaring is no longer apparent. Measure the peak-to-peak amplitude; this must be not less than 5·5V measured at the collector and the emitter of VT3.

PART 6

TECHNICAL INTRODUCTION

Chapter 1

SYMBOLS AND ABBREVIATIONS

List of Contents

List of Tables

List of Illustrations

Introduction

1. The symbols and abbreviations, listed in this chapter, represent the terms used in the descriptive text of the flight simulator systems. The terms are presented

in three tables which correspond to the three basic computers of the flight simulator: the flight computer, the engine computer and the radio aids computer. The tables provide a convenient reference source for the relevant symbols which are defined in an abbreviated form. An additional list of abbreviations, together with standard basic drive, protection and other circuits is included on drawing /001 (para.3). Detailed definitions of the aerodynamic terms, forces, angular velocities and of the systems of the reference axes are included in the introduction to the flight computer (Part 8, Chap.1) where the flight simulator basic design features are also described.

DEFINITIONS

Drawing references

2. Throughout the text of this publication, references are given to illustrations and accompanying drawings. The illustrations in each of the relevant chapters are numbered from Fig.1 onwards; circuit diagrams of units are identified by a capital letter which refers to the drawing size, a five- or six-figure drawing number, and /01 which denotes a circuit diagram.

3. The circuits of the simulator systems are identified in a simplified form by a three figure reference, e.g., /123; the full reference of the Jetstar systems preceeds the three figure group and consists of a five figure number i.e., C94598.

Drawing interconnections

4. Interconnections between circuits drawn on one or more drawings, or interconnections on one drawing, are identified with a reference of the drawing and the number of the connection. In the text, these interconnection references are identified as, for example: interconnection (12). These interconnections are solely inter-drawing cross-references and are not actual terminals.

Standard circuits (/001)

5. Drawing /001 includes an additional list of symbols, and examples of typical standard circuits which are not normally drawn in detail on the system circuits. Also defined in the list of abbreviations are the earth symbols used on the system drawings.

6. The standard circuits show the presentation of the abbreviated circuit symbols, as used on system diagrams, and the actual circuit of the component parts. The following circuits are thus shown on drawing /001:

(1) Two limit circuits of the velodyne drive to servo motors (para.7, 8 and 9)
(2) Actuator- and instrument-drive amplifier connections to the associated motors (para.10)
(3) Relay circuits, which include surge limiting Atmite disc fitted across the relay coil (para.12)
(4) Circuit of lamps fitted within the body of a fault switch (para.13)
(5) Symbol and a short list of computing d.c. amplifiers (para.14).

Velodyne servo limits

7. The velodyne drive limit circuits consist of two similar types, the choice of which depends on the required sense of rotation of the motor and the consequent connection of the motor field winding. The limit circuits contain two limit switches, S1 and S2, that break when the respective limit of motor rotation is reached. For example, if switch S2 is operated (in the first circuit on drawing /001), the coil of relay RL1 is energized, via the diode included between S2 and RL1, if the supply remains positive. The supply to the field winding of motor M is disconnected due to the reverse-biased diode connected between terminal (a) and S1. Simultaneously, operated contact set RL1/1 short-circuits the armature winding of the motor, and the motor stops. When the supply polarity reverses, the coil of relay RL1 is de-energized, the motor field winding is energized via S1 and the diode connected between terminal (a) and the moving pole of S1; released contact set RL1/1 then permits the motor to rotate in the opposite direction. Switch S1 operates similarly when the other limit of travel is reached.

8. The manual/auto switch, S1a and S1b, is provided for manual setting of the servo during tests, servicing, or pre-flight checks. For manual operation the switch must be set to the manual position and, with S1a wired in parallel with RL1/1, the motor will not drive thus permitting the setting of the servo scale pointer to the required position. Switch section S1b, in the manual position, provides a path for the energizing supply to warning lamp LP1 which lights. On completion of the test, the switch must be set to the auto position.

9. The second limit circuit, included on drawing /001, is similar in operation to the first limit circuit, but the circuit configuration is changed to cater for the reversed connections to the motor field winding.

Actuator- and instrument-drive amplifier

10. The third circuit, included on drawing /001, details the connections of the actuator- and instrument-drive amplifiers described in Part 5, Chap.2D. The actuator-drive amplifier provides power drive for servo-actuator motors, via the

manual/auto switch S1a and S1b. For normal operation, the switch is set to auto; when set to the manual position, the motor winding is disconnected from the drive signal and is short-circuited via S1b. The second section of the switch, S1a, connects the energizing supply to light warning lamp LP1.

11. The servo instrument amplifier unit contains two identical amplifiers mounted on one feedback board; the circuit on drawing /001 identifies the pin connections of both amplifiers.

Relays

12. Normally, the coil-resistance of general-purpose relays (resistance 1250 ohms) is not given; for special-purpose relays, the ohmic value of the coil is included inside the symbol. All relay coils are supplied via a series resistor and are bridged by a voltage-dependent resistor (Atmite disc); the resistors and Atmite discs prevent inductive ringing and possible damage to the relay-driving transistors, and remove surges on the coil lines (thus preventing "noise" in the audio system).

Fault switches

13. System fault switches are of the push-button type; each is fitted with an internal, warning and legend-illuminating lamp. Other partial-fault controls consist of ganged potentiometers and switches (not shown on /001) which provide connection of power to adjacent warning lamps if the control is set to any position other than normal (usually mid-position).

Computing amplifiers

14. Drawing /001 also includes a short list of d.c. computing amplifiers which are fully described in the standard units chapters (Part 5).

TABLE 1

Flight computer

Symbol or abbreviation:		Definition:
α	(alpha)	Angle of incidence; defined as the angle between No.1 wind axis and the projection of the aircraft longitudinal axis on to the plane containing No.1 and No.3 wind axes. The angle is considered positive when the airflow (wind) strikes the underside of the aircraft.

TABLE 1 (Cont'd.)

Symbol or abbreviation:		Definition:
$\dot{\alpha} - \omega_2$	(alpha dot minus omega two)	Pitch rate of the aircraft with respect to the earth's axes.
β	(beta)	Angle of bank; defined as the angle between the No.2 wind axis and the projection of the aircraft lateral axis on to the plane containing No.2 and No.3 wind axes. The angle is considered positive when the aircraft is banking to starboard (right wing down).
γ	(gamma)	Angle of yaw; defined as the angle between the No.1 wind axis and the projection of the aircraft longitudinal axis on to the plane containing No.1 and No.2 axes. The angle is considered positive if the yaw is to starboard, i.e., the airflow (wind) is striking the left side of the aircraft.
$\dot{\gamma} - \omega_3$	(gamma dot minus omega three)	Yaw rate of the aircraft with respect to the earth's axes.
Δ	(delta)	Flap deflection angle.
δ	(delta)	Aircraft heading.
δ_P	(delta P)	Outside pressure increment set by the radio aids instructor's PRESSURE potentiometer.
δ_T	(delta T)	Air temperature variation (I.S.A. $\pm \delta_T$) set on the flight instructor's O A T potentiometer.
ζ	(zeta)	Rudder deflection angle. This angle is considered positive when the rudder trailing edge is deflected to starboard (right).
ζ_T	(zeta T)	Rudder trim angle. The positive deflection angle produces an effect on the simulated aircraft similar to that of the rudder positive deflection angle.

TABLE 1 (Cont'd.)

Symbol or abbreviation:		Definition:
η	(eta)	Elevator deflection angle. This angle is considered positive when the elevator trailing edge is deflected upwards.
η_T	(eta T)	Tailplane trim angle. This angle is considered positive when the leading edge of the tailplane is deflected downwards.
θ	(theta)	Pitch angle; defined as the angle between the No.1 wind axis and the earth's horizontal plane. This angle is positive when the aircraft is climbing.
ρ	(rho)	Atmospheric density at specified height (slugs/ft^3).
Σ_{TH}	(sigma thrust)	Total thrust.
ϕ	(phi)	(1) Aileron deflection angle. This angle is considered positive when the port (left) aileron trailing edge is deflected upwards. (2) Phase symbol.
ϕ_T	(phi T)	Aileron trim deflection angle. The positive deflection angle produces effects on the simulated aircraft similar to those of the aileron positive deflection angle.
ω_1	(omega one)	Angular velocity (in rad/s) about the No.1 wind axis; considered positive when the aircraft is rolling clockwise about the No.1 wind axis, and the positive No.1 wind axis is viewed from the centre of origin (C.G.).
ω_2	(omega two)	Angular velocity (in rad/s) about the No.2 wind axis; considered positive when the aircraft is pitching clockwise about the No.2 wind axis, and the positive No.2 wind axis is viewed from the centre of origin (C.G.).

TABLE 1 (Cont'd.)

Symbol or abbreviation:		Definition:
ω_3	(omega three)	Angular velocity (in rad/s) about the No.3 wind axis; considered positive when the aircraft is yawing clockwise about the No.3 wind axis, and the positive No.3 wind axis is viewed from the centre of origin (C.G.).
A.B.		Airbrakes.
A.S.I.		Airspeed indicator.
C.G.		Centre of gravity.
C_L		Coefficient of lift ($C_L = \frac{L}{qS}$).
CLU		Control loading unit.
d_m		Oleo-leg extension and compression term of the mainwheels system of the landing gear.
d_n		Oleo-leg extension and compression term of the nosewheel system of the landing gear.
D		Drag.
$f_{(x)}$		Normalized function, designated by a numerical suffix.
f_Z		Function of Zp.
FF		Fuel flow (in lb/h).
F_1		Forward force (equal to total thrust less total drag) along No.1 wind axis.
$\frac{F_1}{M_T}$		Acceleration along No.1 wind axis.
F_2		Sideforce (along No.2 wind axis).

TABLE 1 (Cont'd.)

Symbol or abbreviation:	Definition:
$\frac{F_2}{M_T}$	Acceleration along No.2 wind axis.
F_3	Vertical force (along No.3 wind axis).
$\frac{F_3}{M_T}$	Acceleration along No.3 wind axis.
g	Gravity constant ($g = 32 \cdot 18$ ft/s^2).
h	Height above airfield.
I.S.A.	International standard atmosphere.
L $(= L_G)$	Gross lift (equal to wing lift plus tailplane lift).
L_B	Buffet lift (lift at which airframe buffeting commences); the buffet lift signal is computed continuously.
L_S	Stall lift (lift at which the aircraft wings stall); the stall lift signal is computed continuously.
L_{SHAKER}	Pre-stall warning lift.
M	Mach number (equal to the ratio of true airspeed of the aircraft to the true local speed of sound).
M_I	Indicated Mach number.
M_E	Electronic Mach number signal.
M_T	Aircraft mass ($\frac{W}{g}$).
M_1	Rolling moment; considered positive if resulting ω_1 is positive.
M_2	Pitching moment; considered positive if resulting ω_2 is positive.

TABLE 1 (Cont'd.)

Symbol or abbreviation:	Definition:
M_3	Yawing moment; considered positive if resulting ω_3 is positive.
n_1	Sine of angle between flightpath and the horizontal plane.
$n_1 g$	Component of acceleration due to gravity along the line of flight.
q	Dynamic pressure ($q = \frac{1}{2}\rho V_T^2$).
S	Aircraft wing area (ft^2).
TH	Engine thrust.
V_T	Aircraft true airspeed (ft/s).
V_{NE}	Maximum permissible airspeed.
V_2	Airspeed component along No.2 wind axis.
W	Aircraft weight (lb).
Z_P	Aircraft barometric height (ft).
Z_T	Aircraft height above sea level.

Notes...

(1) A single dot surmounting an angle symbol signifies an angular velocity; two dots signify an angular acceleration, e.g.:

γ = yaw angle
$\dot{\gamma}$ = rate of change of yaw angle
$\ddot{\gamma}$ = acceleration of yaw angle.

(2) A single dot surmounting a velocity symbol denotes an acceleration; e.g.:

V_T = true velocity
$\dot{V}_T$ = true acceleration along the No.1 wind axis.

TABLE 2

Engine computer

Symbol or abbreviation:		Definition:
δ_{SUFFIX}	(delta suffix)	Instructor's variation of an engine parameter.
ΣTH	(sigma thrust)	Total thrust.
EGT		Exhaust gas temperature.
EPR		Engine pressure ratio.
FF		Fuel flow.
N		Engine speed (rev/min).
N_1		Speed of engine No.1.
P_{OIL}		Oil pressure.
RPM		Indicated engine speed (rev/min).
T or OAT		Static, outside air temperature.
T_1		Temperature of engine air intake.
T_{OIL}		Oil temperature.

TABLE 3

Radio aids computer, flight systems and instruments

Symbol or abbreviation:		Definition:
δ	(delta)	Aircraft heading.
δ_W	(delta W)	Wind direction set on the radio aids WIND DIRECTION potentiometer.
ADF		Automatic direction finding.
DG		Directional gyro.

TABLE 3 (Cont'd.)

Symbol or abbreviation:	Definition:
DME	Distance measuring equipment.
E	Movement or distance along a parallel (eastings).
GP or GS	Glide path or glideslope (ILS).
h.f.	High frequency.
HF	High frequency radio system.
I/C	Intercommunication system.
IFS	Integrated flight system (Collins).
IIS	Integrated instrument system (Sperry).
ILS	Instrument landing system.
LOC	Localizer (ILS).
N	Movement or distance along a meridian (northings)
PDI	Pictorial deviation indicator (Sperry).
RMI	Radio-magnetic indicator.
v.h.f.	Very high frequency.
VHF	Very high frequency system.
VHF COM	Very high frequency tele-communication system.
VHF NAV	Very high frequency radio-navigation system.
VOR	V.H.F. omni-range beacon.
V_W	Wind speed.
X	East/west axis of a chart.

TABLE 3 (Cont'd.)

Symbol or abbreviation:	Definition:
Xa	East/west distance of aircraft from chart datum (left-hand bottom corner).
Xs	Eastings of small-scale chart datum (left-hand bottom corner) from large-scale chart datum (left-hand bottom corner).
Y	North/south axis of a chart.
Ya	North/south distance of aircraft from chart datum (left-hand bottom corner).
Ys	Northings of small-scale chart datum (left-hand bottom corner) from large-scale chart datum (left-hand bottom corner).
Z_{AH}	Airfield height.
Z_G	Aircraft height above ground (airfield).
Z_P	Pressure height.

Radio aids symbols (/300)

15. Drawing /300 shows the symbols for amplifiers and logic elements used on system drawings of the radio aids computer. The a.c. amplifier symbols each have a direct physical counterpart; the logic symbols are, however, of a more general nature and do not necessarily exist as separate elements.

16. The normal convention for PNP transistor logic is used, i.e., 0V represents logic 0, and a negative level (-12V) represents logic 1. Provision is made for conversion to positive logic, where logic 1 = +12V, by means of the P converter element.

17. Drawing /300 defines the logical operation of the logic elements; three of the symbols require further explanation. These are the non-inverting buffer and the flip-flop symbols.

18. The symbol for a non-inverting buffer has also been adapted for other logic functions, an example of such alternative usage being shown on the logic diagram of the frequency comparator board, drawing C99090/01 (sheet 2). In this instance, the symbol shows two inputs, 1 and 2, and the element acts as an exclusive-OR gate, the operation of which is defined as:

$$c = (a + b) \cdot \overline{(a \cdot b)}$$

The exclusive-OR gate uses both positive and negative logic inputs.

19. The symbol for the +FF flip-flop shows set and reset inputs and outputs as S and R. The logic levels, present on the S and R inputs, steer the positive triggering pulse-edge to set or reset the flip-flop. For example, if the flip-flop is in the set state (logic 1 on the set output), then the trigger pulse can only reset it if the reset input is a logic 1 and the set input a logic 0. The set and reset outputs can be used as steering inputs to a succeeding flip-flop stage in a counter.

20. The FF flip-flop functions similarly to the +FF flip-flop; only the set output is used, however, in this instance.

PART 7

ENGINE COMPUTER

Chapter 1

INTRODUCTION TO ENGINE COMPUTER

List of Contents

List of Illustrations

General

1. The engine computer of the flight simulator is concerned with the simulated aircraft power-plant quantities that are required for a realistic representation of the behaviour of the aircraft engines, e.g., indication of the engine parameters on the flight instruments, the effects of the developed power on the flight behaviour of the aircraft and the representative noise effects, etc. Because each aircraft engine is simulated individually and the respective circuits are, generally, similar in design and operation, only engine No. 1 systems are described.

2. The engine quantities are computed as functions of throttle lever setting (T/L), Mach number (M), height (Z), and dynamic pressure (q) which includes the effects of air density variation as a function of outside air temperature (O A T), height and forward speed. The setting of the throttle levers and the computed atmospheric variables establish the resulting engine speed, the developed thrust and the pitch of the simulated engine noise. The engine speed affects the fuel flow-rate, the engine oil temperature, the airspeed and thrust, etc. The necessary information is indicated to the pilots by means of gauges, indicators and controls similar to those in the actual aircraft.

3. Each chapter is accompanied by the relevant system drawings and illustrations which are detailed in the list of illustrations and are referred to in the text. The system diagrams are identified as, e.g., C94598/123; the C94598 reference identifies all Jetstar flight simulator systems; the suffix /123 denotes a particular system.

Engine simulation

4. Four JT 12A-6 jet engines are fitted to the Jetstar aircraft. Each engine is simulated by a positional servo and associated circuits. Each engine is started individually and the engine speed is registered by the respective servo. The servo shaft drives a number of R P M (N) potentiometers and the engine tachometer. The voltages from the wipers of the N potentiometers constitute d.c. signals that are fed to the engine computing circuits, such as the thrust system, oil temperature and pressure system, fuel flow circuits, exhaust gas temperature, etc. The N signals are corrected for atmospheric air temperature and density variations before the final computation is made, and the result is supplied to the appropriate engine instruments and to the flight computer circuits. The engine speed signals are applied to the engine noise units, and, when mixed with the air noise signals, provide audio representation of the engine and aircraft noises, via loudspeakers, in the cockpit/ fuselage section of the simulator.

5. The instructor's console, mounted in the fuselage, provides facilities for variation of the normal engine and flight computer signals, thus introducing faults and failures in the engine systems.

6. Engine starting procedure is in accordance with normal aircraft practices; the starting controls are mounted on panel RD. The engines and their respective ignitor units are selected individually by the engine selector switch; the starting sequence is initiated by operation of the START switch. When "engine lit" conditions are achieved, the engine speed is determined by the setting of the associated throttle lever and by atmospheric factors. The engine power (thrust) is proportional to the quantity, proportion, and temperature of the fuel/air mixture fed to the engine.

7. The operational conditions of each engine are indicated by instruments which monitor the fuel flow rate (lb/h), exhaust gas temperature (^{o}C), engine speed (%), oil pressure (lb/in^2) and oil temperature (^{o}C). The outside air temperature is indicated on the FREE AIR TEMP. gauge (^{o}C).

Simulated engine systems

8. The operation of an engine system is shown in diagrammatic form in Fig. 1 which represents the computation systems and the interconnection of the more important engine computer signals.

9. The input and output signals can, in some instances, be representative of several functions of the same quantity, and certain factors, or functions of these factors, are common to all four engine computers, i.e., Mach number (M), height (Z) and dynamic pressure (q). Some of the computations include a temperature variation factor (δ_T) which is selected by the instructor on the outside air temperature potentiometer. Adjustment of this potentiometer enables the instructor to introduce the effects of temperature changes upon the computed engine quantities. The following text contains a brief explanation of the various sections of the engine computer. Each section produces an engine quantity as either an output voltage or servo position.

10. The starting cycle of the engines is simulated by the engine start and relight system (Chap. 3). Hot start and engine failure conditions can be introduced by the instructor's controls and switches.

11. The fuel system (Chap. 2) provides fuel contents and fuel flow rate information which is displayed on the appropriate instruments. The fuel tanks are represented by integrating amplifiers that are fed with signals corresponding to the refuelling and depletion rates; the outputs of the integrators provide a signal for the individual fuel gauges. The fuel flow rate is derived from functions of Mach number (M), aircraft height (Z), air temperature variation (δ_T), engine speed (N) and instructor's preset fuel flow variation (δ_{FF}).

12. The engine speed computation (Chap. 4) is performed by summing the following quantities: throttle lever setting (T/L), Mach number (M), dynamic pressure (q) and instructor's (preset) engine speed variation (δ_N). The sum of these signals provides the drive for the engine speed servo and for the pilot's PERCENT RPM indicator which registers the engine speed as a percentage of the maximum engine rev/min. The servo-driven N potentiometers supply signals, corresponding to the computed engine speed, to the circuits of the flight and engine computers, and to the noise system.

13. The engine thrust system (Chap. 5) computes the developed thrust from the N potentiometers (para. 12) and from the engine pressure ratio (EPR). The resulting signal voltage is applied to the drag system of the flight computer for the computation of aircraft speed. Reverse thrust can be selected on landing; the reverse thrust signal is added to the aircraft drag signals when the aircraft has touched down.

14. The engine indicator system (Chap. 6) comprises the engine instruments that are fed with the respective signals from the engine computing systems. The engine speed tachometers are driven remotely by the engine speed servos. EPR is computed from functions of aircraft height (Z), Mach number (M) and engine speeds (N); the pressure is indicated on the P.R. gauge and registers pressure variations due to temperature changes (δ_T) and icing. Oil temperature is computed from signals representing engine speed (N), fuel flow (FF) and intake temperature (T_1). Oil pressure is displayed on the respective OIL PRESS indicator which is coupled to a positional servo driven mainly by the engine speed (N) signals. The exhaust gas temperature is indicated on the EXH TEMP gauge which is electrically driven by the sum of signals representing the intake temperature (T_1) and engine speed (N).

15. Visual warning of fire and danger conditions is given by lamps which are lit when the flight instructor operates the FIRE ZONE 1 or 2 switches.

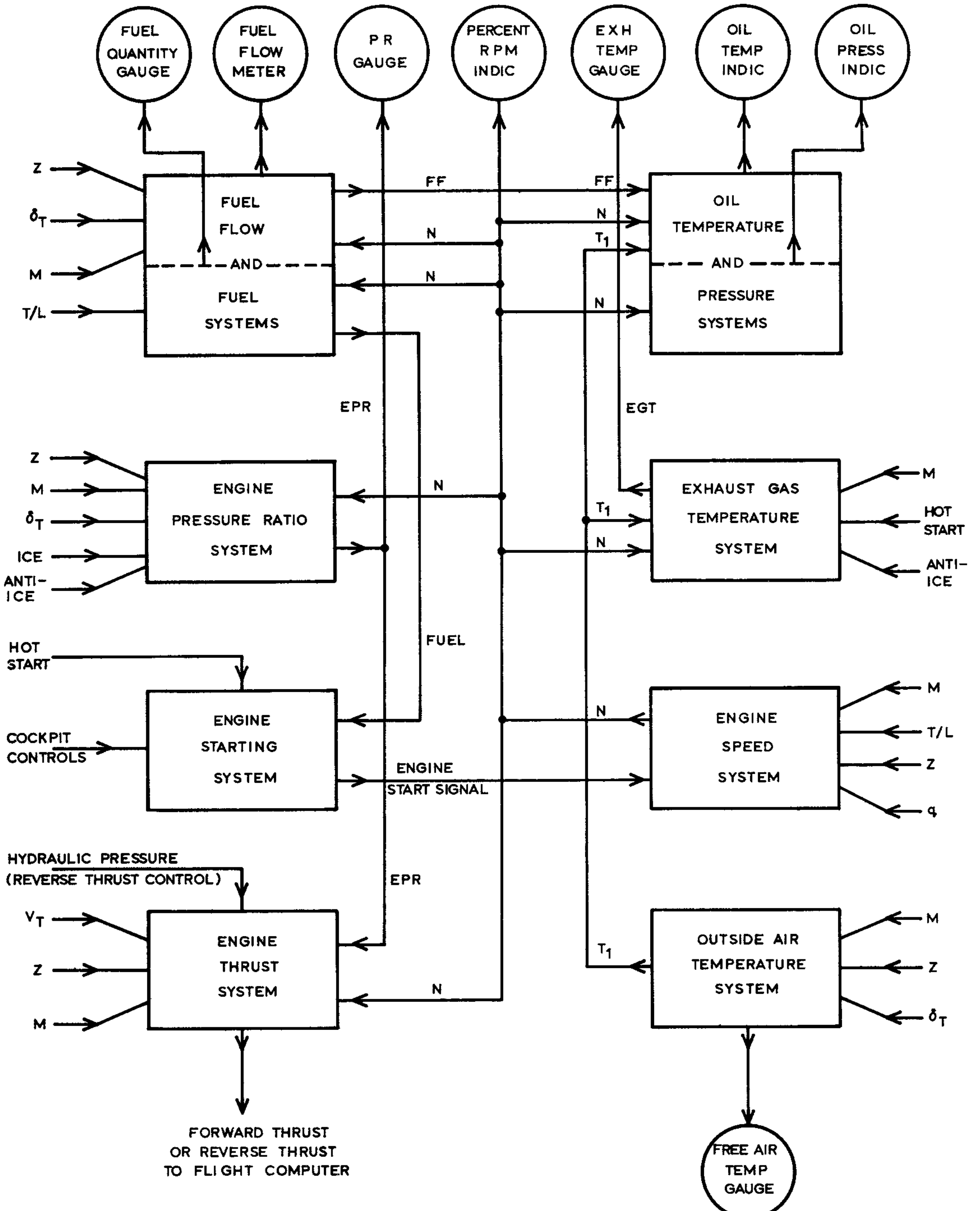
16. The engine computer ancillaries (Chap. 7) include the circuit of the FREE AIR TEMP. gauge, the indication of which is based on the Mach number (M), outside air temperature variation (δ_T) and height (Z). The computed air temperature provides also the intake air temperature (T_1) signal for the engine computer.

Instructor's controls

17. The flight instructor is provided with controls and switches which enable him to introduce faults or complete failures of the engine systems. Each potentiometer is coupled to a switch which, in any position other than the 0 position (usually mid-point on the associated scale), causes the adjacent lamp to light. Thus, any fault conditions and settings are clearly indicated to the instructor.

18. The computation of the engine parameters is affected by the settings of the instructor's controls positioned on panel XF/AM such as the O A T potentiometer and the ICE switch; signals from these controls provide common terms to the engine and flight computer. The four sets of potentiometers and switches on panels XF/AD, /AE, /AF and /AG are independent controls for each engine; by operation of these controls, the instructor can vary the indication (within certain limits) of the following engine computer systems: engine speed (RPM), engine temperature and pressure, fuel flow, and oil temperature and pressure. In the circuit diagrams the respective potentiometers are annotated $\delta_{function}$ to indicate that the range of $\pm$ adjustments is an instructor-controlled increment.

19. Engine systems failure switches are also quadruplicated and provide the following facilities: engine failure, hot start, failure of reverse thrust system, fire in zone 1 or zone 2, and failure of the fire warning system.



NOTES

V_T = TRUE AIRSPEED		M = MACH NUMBER	
Z = AIRCRAFT HEIGHT		FF = FUEL FLOW	
T/L = THROTTLE LEVER		T_1 = ENGINE INTAKE TEMPERATURE	
δ_T = TEMPERATURE VARIANT		N = ENGINE SPEED	
q = DYNAMIC PRESSURE		EPR = ENGINE PRESSURE RATIO	

Fig 1 Engine computer – block diagram

Chapter 2

FUEL SYSTEM

List of Contents

List of Illustrations

Introduction

1. The fuel system computes the drive signals for the fuel-contents and fuel-flow gauges, and provides warning lamp indications of the state of the various fuel valves, fuel de-icing valves and fuel pumps. Included in the system is fuel tank switching, (crossfeed, etc.): this is associated mainly with the fuel low-pressure warning system and does not affect the fixed rates of fuel depletion displayed on the fuel-contents gauges.

2. The functioning of the fuel system is dependent on the availability of the aircraft electrical power supplies, and on the setting of the aircraft fuel controls and the instructor's fuel function and fault controls.

FUEL CONTENTS SYSTEM

General

3. The aircraft fuel is carried in four main tanks and two auxiliary pod-tanks. Normally, the main tanks supply their respective engines; the auxiliary tanks are connected to the common crossfeed line and their contents are used first. If crossfeed connections between tanks are selected, various combinations of tanks-to-engines can be achieved. In the simulated fuel system, however, all tanks should be used simultaneously, because the crossfeed connections do not affect the indication of the fuel gauges, and the depletion rate is constant for all tanks and for all flying conditions.

4. Each fuel tank contains an electrically-driven fuel boost pump which delivers fuel under pressure to the engines, and provides rapid jettisoning of fuel in an emergency. Each engine drives a mechanically-operated fuel pump which supplements the electrically-driven boost pump. Figure 1 shows the general layout of the fuel system.

5. In the flight simulator, the six fuel tanks are represented by individual circuits that provide predetermined rates of fuel depletion (equal to the normal engine consumption), fuel jettison and re-fuelling of tanks. These functions are selected by the crew and are controlled by the flight instructor. The crew's fuel controls and fuel contents gauges are contained on the "fuel management panel" (on the centre instrument panel).

6. Fuel control valves (crossfeed, etc.), fuel boost pumps, engine-driven fuel pumps, and functions which may be selected by the crew (e.g., fuel filter de-icing) are represented by relay switching circuits.

Main tanks (/019)

7. The four circuits of the main fuel tanks are similar and only the circuit of tank No.1 (shown on drawing /019) is described. Each main fuel tank circuit includes an integrating amplifier and four tank fuel-level discriminators. The output of the integrating amplifier drives the associated fuel quantity gauge. Each of the fuel-level discriminators operates a relay at a preset amplifier output potential which represents one of four levels of tank contents.

8. The aircraft fuel-contents measuring system is electrically driven from the aircraft a.c. supplies; this is represented by relay 14F/T3/RL20 which is energized when the main a.c. busbar supplies are available to the No.1 and 4 tank circuits; operated contact set /T3/RL20/1 then connects +50V to the input circuit of amplifier 14FC. The input signals are controlled by the instructor's RUN and REFUEL switches, XF/AB/S20 and /S21, respectively, contact set 14F/T1/RL13/2 of the "tank empty" relay (para.11(4)) and contact set 14F/T1/RL9/1 of the "tank full" relay (para.11(1)). The RUN switch controls the "No.1 tank run" relay 14F/T1/RL14.

9. For "normal" engine operating conditions, the RUN switch must be operated; a 1V signal, from potential divider 14F/T5/R2 and /R4, is then applied to the amplifier input via operated contact set 14F/T1/RL14/1 and scaling resistor /R3. The tank is refuelled by operation of the REFUEL switch with the RUN switch set to off; in this instance, a -50V signal is fed to the amplifier input via released contact set /RL14/2 and scaling resistor /R8. If fuel jettison or reduction of the fuel contents is required, the RUN and REFUEL switches are operated simultaneously, and a 1V signal from the junction of /R5 and /R7 is fed to the amplifier via /R8. The respective times of tank depletion, refuelling and jettison are as follows:

(1)	Normal "run" tanks No.1 and 4	-	3 hours, 12 minutes
(2)	Normal "run" tanks No.2 and 3	-	3 hours, 24 minutes
(3)	Refuelling	-	16 seconds
(4)	Fuel jettison	-	13 minutes, 30 seconds.

10. The output signal of amplifier 14FC varies from +100V (tank full) to -100V (tank empty). The output signal provides a direct drive to the FUEL QUANTITY gauge CA/AC (para.12) and to the four "fuel level" discriminators (para.11).

Fuel level discriminators

11. The transistorized-relay circuits of the four fuel level discriminators are similar in operation, and are arranged to energize the associated relays at the following conditions:

(1) Tank full : at approximately +100V output the "No.1 tank full" relay 14F/T1/RL9 is energized, and its contact set /RL9/1 disconnects the -50V signal which is fed to amplifier 14FC via the REFUEL switch.

(2) Tank contents less than 1000 lb : at approximately -33V output the "No.1 tank < 1000 lb" relay /RL12 is energized, and its contact set /RL12/1 operates in the circuit of the jettison valve (para.28) and inhibits the operation of the crossfeed valves during jettison, when the fuel contents of No.1 tank are reduced below 1000 lb.

(3) Tank contents less than 300 lb : at approximately -80V output the "No.1 tank < 300 lb" relay /RL10 is energized and its contact set /RL10/1 connects the supply to the LOW SUMP LEVEL warning lamp (para.40).

(4) Tank empty : at approximately -100V output the "No.1 tank empty" relay /RL13 is energized; contact set /RL13/1 disconnects the "No.1 tank" from the crossfeed system (para.35), and contact set /RL13/2 disconnects the +50V signal from the input of amplifier 14FC (para.8).

Fuel quantity gauge

12. The TANK NO.1 FUEL QUANTITY gauge CA/AC consists of a moving-coil meter (3mA f. s. d.) which is driven by the output potential of amplifier 14FC (para.10). The reading displayed varies with the applied voltage from 0 lb at -100V to 3000 lb at +100V. The gauge is connected to the amplifier via resistor /T5/R23 and diode /T5/MR9 which ensures that the gauge indications cannot extend below the zero mark due to the -100V bias at the meter negative terminal. This bias is obtained from the -300V supply via resistor /T6/R24 and is stabilized by Zener diode stack /T5/MR10.

Auxiliary tanks (/020)

13. The basic circuits of the auxiliary fuel tanks are similar to those of the main tanks (para.7), except that the twin-pointers of the fuel contents gauge are driven by individual positional servos via reduction gears, and only two fuel level discriminators are used in each auxiliary tank circuit. Only the left auxiliary pod-tank circuit is described.

14. Refuelling and defuelling circuits, at the input of integrating amplifier 14EC, are controlled by the instructor's RUN and REFUEL switches, XF/AB/S25 and /S26 respectively, and by No.1 contact sets of the "tank full" and "tank empty" slave relays, 14E/T1/RL6 and /T1/RL4, respectively. The REFUEL switch is included directly in the amplifier input circuit; the slave relays are controlled by the RUN

switch and by the tank level-discriminator relays (para.16) as follows:

(1) Slave relay 14E/T1/RL2: controlled by the RUN switch
(2) Slave relay /T1/R6: controlled by the "tank full" relay /T2/RL1
(3) Slave relay /T1/RL4: controlled by the "tank empty" relay /T2/RL2.

15. Contact sets of the slave relays provide the following functions:

(1) Contact set 14E/T1/RL4/1 disconnects the +50V signal from the input of amplifier 14EC when the tank becomes "empty"
(2) Contact set /T1/RL6/1 disconnects the -50V refuelling signal from the amplifier input when the tank is "full"
(3) Contact sets /T1/RL2/1 and /RL2/2 operate when the RUN switch is operated for normal or jettison depletion rates of the tank contents
(4) Contact set /T1/RL4/2 is not used
(5) Contact set /T1/RL4/3 operates in the fuel control valves system (para.35).

16. The input signals to amplifier 14EC are obtained from potential dividers, via summing resistors, to limit the amplifier output signal to +80V (tank full) and -100V (tank empty). These two levels are detected by the transistorized-relay circuits of the level-discriminators, and the respective "tank full" relay /T2/RL1 and "tank empty" relay /T2/RL2 are energized when the corresponding levels are reached. The times of refuelling, full depletion and jettison are as follows:

(1) Refuelling - 20 seconds
(2) Normal depletion - 4 hours, 48 minutes
(3) Jettison - 13 minutes, 40 seconds.

17. The output of amplifier 14EC is fed, via operated contact set /T1/RL1/1 of the "main a.c. available" relay and scaling resistor /T3/R22, to servo drive amplifier 14EE/a and the associated buffer and instrument drive amplifier 14E/T5a. The servo positional feedback is obtained from servo-driven potentiometer CA/AE/RV1 via operated contact set /T1/RL1/2 of the "main a.c. available" relay and scaling resistor /T3/R23.

18. The servo response is set by potentiometer /T3/RV501 in the negative feedback loop of the servo drive amplifiers. The servo motor CA/AE/1 drives the LH pointer of the dual gauge.

<u>Fuel control valves</u> (/018)

19. The HP (high pressure) cocks, engine shut-off, isolation, and crossfeed valves

associated with each tank and engine are simulated, individually, by relays which are operated from the main and essential d.c. busbars via aircraft circuit breakers and switches.

20. Drawing /018 shows the circuit of the valves associated with the No.1 main fuel tank, and the crossfeed and inter-connection valves common to all tanks. The four main tank boost pumps are also shown, each being represented by a relay. The circuits of the individual main tanks valves are similar and only the No.1 tank valve circuit is described.

High-pressure cocks

21. The opening of the No.1 engine HP cock is simulated by operation of the "HP cock open and RPM > 8·25%" relay 14F/T1/RL8. This relay is energized during the No.1 engine start-up procedure when the No.1 throttle lever is advanced to at least 7·5 per cent of its full travel and the No.1 engine speed exceeds an indicated 8·25 per cent of the maximum RPM. The +27V relay-energizing voltage is then routed via the T/L switch card XA/AA/RV3 and N_1 switch card 14BS/RV11 to the coil of /RL8. The operation of the relay is delayed by capacitor /C1.

22. Operated contact set /RL8/1 completes the energizing circuit of the "fuel available" relay /RL5 (para.34), contact set /RL8/2 is not used, and contact set /RL8/3 operates in the noise system (Part 10, Chap.11) where it connects power to the cockpit loudspeaker units which reproduce the engine noise.

Isolation valves

23. The isolation valves of the main tanks are represented by relays which are energized when the respective FUEL TANK ISOLATION switches on panel AC are selected to ON. Operation of these relays depends on the availability of the main d.c. busbar supplies which are fed via the ISOLATION VALVES 1 & 4 circuit breaker SH/93 and switch AC/AM to the circuit of "isolation valve tk 1" relay 14F/T1/RL2. The relay circuit is self-holding, via the No.2 contact sets of /RL2, from the general +27V supply which is isolated from the busbar supplies by diode /MR30. When the relay is energized, the operated No.1 contact set provides a path for the relay-releasing voltage, from the OFF pole of switch AC/AM, to the junction of /RL2 and /R2. Operated contact set /RL2/3 disconnects the energizing voltage to the "fuel available, eng. 1" relay 14F/T1/RL5 (para.35). Circuit breaker SH/93 also supplies the identical circuit of the "isolation valve tk 4" relay 14F/T4/RL2 (not shown on the circuit).

Fuel shut-off valves

24. The circuit of the "shut-off valve, eng. 1" relay, 14F/T1/RL1, is similar to that of the isolation valve relay /RL2 (para. 23). The aircraft essential d.c. busbar supplies are fed via the ENG 1 FUEL SHUTOFF VALVES circuit breaker PP/46 which supplies the circuit of "shut-off valve, eng. 1" relay /RL1 when the FIRE 1 PULL handle AC/AM is pulled. Contact set /RL1/3 is in series with contact set /RL2/3 (para. 23); when operated, it disconnects the supply to the "fuel available, eng. 1" relay 14F/T1/RL5 (para. 35).

Crossfeed valves

25. Operation of crossfeed switch CA/BA, on the fuel management panel, energizes the coil of the "crossfeed valve, eng. 1" relay 14F/T1/RL3 from the essential d.c. busbar supply, via diode /MR33, released contact set /RL4/1 ("fuel reserve tank 1" relay, para. 28) and CROSSFEED 1 circuit breaker PP/51. Contact set /RL3/1 connects a +27V supply to the coil of relay /RL3; contact set /RL3/2 operates in the circuit of the four "fuel available" relays (para. 36), and contact set /RL3/3 operates in the fuel pressure warning lights system (para. 49).

26. Relay /RL3 is released by contact set /RL4/2, which connects an equalizing voltage across /RL3 coil when either:

(1) Switch CA/BA is set to off and relay /RL4 is released (para. 28)
or (2) Relay /RL4 is energized (para. 28) because No. 1 tank fuel contents are less than 1000 lb.

Jettison valves

27. Jettison of fuel from the right and left tanks is controlled by two, L and R, FUEL JETTISON switches AC/CA and AC/BA, respectively. The instructor's RUN and REFUEL switches must also be operated together, when jettison is selected, to simulate the increased fuel depletion displayed on the respective fuel gauges (para. 9). Operation of the tank crossfeed valves is inhibited during jettison when the level of the tanks is less than 1000 lb.

28. Operation of the FUEL JETTISON L switch AC/CA energizes the coil of "fuel reserve tank 1" relay 14F/T1/RL4 from the essential d.c. busbar supply, via the FUEL JETTISON LH circuit breaker PP/61, provided that contact set /RL12/1 (of the "No. 1 tank < 1000 lb" relay) is released (para. 11(2)). Operated contact set /RL4/1 open-circuits the energizing supply from the crossfeed switch CA/BA to the coil of /RL3 (para. 25). Operated contact set /RL4/2 de-energizes /RL3 by applying

an equalizing voltage, from circuit breaker PP/61, across the relay coil.

Tank interconnect and crossfeed valves

29. The two "interconnect tanks 1 and 2, 3 and 4" relays 14F/T1/RL19 and /T3/RL19 are controlled by the two MAIN TANK INTERCONNECT switches, AS/AF and /AE, respectively. The "crossfeed switch" relay /T2/RL19 is controlled by the main crossfeed switch CA/AZ on the fuel management panel. The essential d.c. busbar supply to the three switches is routed via the INTCON circuit breaker PP/50.

30. The circuits of the three relays are similar to the circuit of /T1/RL2 described in para.23, except for component references and the INTERCONNECT VALVE instructor's warning lamp XF/AB/LP14 which is connected to the coil of the main "crossfeed switch" relay /T2/RL19 and which lights when the relay is operated.

31. The No.3 contact sets of the three relays are connected in the circuit of the "fuel available" relays (para.36). The No.4 contact set of the main "crossfeed switch" relay /T2/RL19 operates in the fuel pressure warning system (para.49).

Boost pumps (/018)

32. Four relays, /T1/RL17, /T2/RL17, /T1/RL18 and /T2/RL18, represent the four main tank boost pumps which are controlled by the BOOST PUMPS switches CA/AH, /AJ, /AM and /AN, respectively. The circuits of the four boost pumps relays are similar and only the circuit of the "No.1 boost pump" relay /T1/RL17 is described. The second sections of the BOOST PUMPS switches operate in the flasher-circuits of the "fuel at eng. 1, HP cocks closed" relays (para.47).

33. Operation of boost pump switch CA/AH energizes the coil of relay /T1/RL17 from the main d.c. busbar supply via contact set /T1/RL20/3 (of the "main d.c. on" relay, para.40) and series-connected TANK 1 FUEL BOOST PUMPS circuit breakers SH/94 (PUMP) and SH/95 (CONT). Contact set /T1/RL17/1, connected to the junction of switch CA/AH and circuit breaker SH/94, via diode /T1/MR34, provides an earth return for the LOW FUEL PRESS lamp CA/AT (para.44(2)) if relay /T1/RL17 is de-energized (because of a fault in the aircraft electrical supplies) and switch CA/AH is selected to ON. Failure of the boost pump is indicated when lamp CA/AT is lit continuously.

Fuel available relays (/018)

34. Energized relays /RL5 in positions 14F/T1, /T2, /T3 and /T4, represent the availability of fuel to the respective engines. These relays are controlled by contact

sets of the various "valve" relays, and their contact sets, when operated, provide the "fuel available" to the fuel flow system (No.2 contact set, para.63) and to the engine starting system (No.3 contact set, Chap.3); No.1 contact set is wired in the circuit of the LOW FUEL PRESS lamp (para.44(3)) but it is short-circuited and not functional.

35. Normally, when fuel is available, each relay is energized from the -27V supply via the released contact set of the associated "fuel tank empty" relay (e.g., 14F/T1/RL13/1 for tank No.1, para.11(4), and 14E/T1/RL4/3 for left auxiliary tank, para.15(5)), tank circuit-isolating diode (/T4/MR21), released contact set of the "isolating valve" relay (/RL2/3, para.23), released contact set of the "shut-off valve" relay (/RL1/3, para.24) and operated contact set of the "HP cock open and RPM > 8·25%" relay (/RL8/1, para.22).

36. If, for example, the No.1 tank becomes empty (relay /T1/RL5 de-energized), relay /T1/RL5 can be re-energized by a suitable crossfeed or tank-interconnect selection, e.g., via operated contact set /T1/RL19/3 of the "interconnect tank 1 & 2" relay (para.31 or via any operated contact sets of the "crossfeed valves" relays (e.g., 14F/T1/RL3, para.25) as evident from the circuit diagram. Operation of the respective FIRE PULL handle (operated contact set /RL1/3) and/or closing of the respective throttle lever (released contact set /RL8/1) isolates the "fuel available" relays from the fuel valve- and crossfeed-circuits.

37. When the various electrically-operated valves are selected and current is drawn from the aircraft electrical supplies, the simulated increase in current demand is shown on the respective LOAD meter, (electrical system, Part 10, Chap.1). The fuel valve- and crossfeed-circuits are connected to the LOAD meter circuits via four individual interconnections, e.g., the circuit of NO.1 GENERATOR LOAD meter is connected to the No.1 tank fuel valves via interconnection (21).

38. An additional fuel selection condition, i.e., fuel tank supplies selected but HP cocks not opened, is fed from /RL8/1 to the LOW FUEL PRESS warning lamp circuits (para.48) via four individual interconnections, e.g., interconnection (25) for the No.1 tank circuit. The LOW FUEL PRESS warning lamp circuits are also fed with a signal representing the "fuel available and HP cocks opened" condition via four interconnections, e.g., interconnection (34) for No.1 engine circuit.

Warning indicators (/017)

39. The warning lamps associated with the fuel system are situated on the fuel management panel CA, and consist of four LOW SUMP LEVEL lamps, two auxiliary tank fuel PRESS LOW lamps and four engine LOW FUEL PRESS lamps. Included on drawing /017 are the circuits of the FUEL FILTER CLOGGING lamps, fuel heat valves, and the circuit of the AIR BLEED OPEN lamp. All these lamps have a press-to-test facility.

Low sump-level lamps

40. When lit, the LOW SUMP LEVEL lamps CA/AP, /AQ, /AR and /AS indicate that the fuel contents of tanks 1 to 4, respectively, are less than 300 lb. The four lamp circuits are identical and are supplied with the +27V supply via operated contact set 14F/T1/RL20/1 (of the "main d.c. on" relay) and the fuel LOW LEVEL WARNING circuit breaker SH/99. The "main d.c. on" relay /T1/RL20 and the "essential d.c. on" relay /T2/RL20 are operated when the respective aircraft d.c. busbars (electrical system, Part 10, Chap.1) are energized. The lamp circuits are completed by operated No.1 contact sets of relays /RL10 in positions 14F/T1, /T2, /T3 and /T4, respectively. These relays are operated by the main tank 300 lb fuel-level discriminator (para.11(3)).

Auxiliary tanks low-pressure lamps

41. When lit, the auxiliary tank PRESS LOW lamps CA/AX (left) and CA/AY (right) indicate failure of the auxiliary tank boost pumps; the low-pressure warning is repeated by the LOW FUEL PRESS lamp on the annunciator warning panel when either or both lamps are lit. The +27V supply to both lamps is routed via operated contact set 14F/T2/RL20/1 (of the "essential d.c. on" relay, para.40) and the FUEL WARN LT LOW PRESS circuit breaker SL/41. The circuits of the two lamps are similar, and only the circuit and operating conditions of lamp CA/AX are described.

42. The circuit of lamp CA/AX is completed via the series-connected auxiliary tank boost pump ON/OFF switch CA/AK, FUEL JETTISON switch AC/CA and the flight instructor's LOW PRESSURE fault switch XF/AB/S27. When the auxiliary tank fuel system is operating normally (i.e., the instructor's fault switch XF/AB/S27 open and the FUEL JETTISON switch AC/CA set to off), operation of the boost pump switch CA/AK to ON provides sufficient current, via capacitor XF/AB/C1, to light the lamp for a short period. This indicates temporary low pressure in the system before the normal fuel pressure is attained, and provides a visual indication of correct function of the auxiliary power boost pump during pre-flight checks. If the FUEL JETTISON switch AC/CA is switched off and the boost pump switch CA/AK is set to ON, the brief lighting of the warning lamp simulates the balancing of the pressure differential in the various fuel pipes.

Low fuel-pressure lamps

43. Warning of insufficient fuel pressure to the four engines is given by four independent ENG 1 to 4 LOW FUEL PRESS lamps CA/AT, /AU, /AV and /AW, respectively; the lamp circuits are similar except for component references and only the circuit of lamp CA/AT is described.

44. The +27V supply to all four lamps is routed via contact set 14F/T2/RL20/1 (of the "essential d.c. on" relay, para.40) and the FUEL WARN LT LOW PRESS circuit breaker SL/41 (para.41). The warning indication of lamp CA/AT can be either a steady light or a flashing light depending on the nature of the fuel pressure failure. A steady light indicates that the following conditions prevail:

(1) Failure of fuel pressure from No.1 tank - introduced by operation of the instructor's LOW PRESSURE fault switch XF/AB/S22.

(2) Boost pump selected by switch CA/AH (para.33), but aircraft electrical power not available at the boost pump. When this fault is experienced, interconnection (36) is earthed by released contact set 14F/T1/RL17/1 (/018) and operated BOOST PUMPS switch CA/AH; the "No.1 boost pump on" relay /RL17 can be de-energized if the "main d.c. on" contact set /T1/RL20/3 (para.40) is released, or if either of circuit breakers SH/94 or /95 (para.33) is tripped.

(3) Fuel available, but boost pump not selected; this condition is represented by released contact set 14F/T1/RL16/2, of the "fuel at engine 1, HP cock closed" relay /RL16 (para.47), which provides earthing of the lamp circuit via short-circuited contact set /T1/RL5/1.

45. Lamp CA/AT flashes at regular intervals in the following two instances:

(1) Fuel selection is correctly made, but No.1 engine HP cock is closed. Periodic earthing of the lamp is made by contact set 14F/T1/RL16/2; the coil of relay /RL16 is connected in a flasher circuit (para.48) when the second section of the BOOST PUMPS switch CA/AN is set to ON and interconnection (32) is connected to the -27V supply via released contact set 14F/T1/RL8/1 (para.35 and 36). The circuit of relay /RL8 is described in para.21.

(2) During pre-flight checks (engines not lit), if any one of the BOOST PUMPS switches is set to ON, and the main fuel tanks are connected to the crossfeed fuel line; this condition is achieved by contact set 14F/T1/RL16/2 of the flasher circuit relay /RL16 (para.48) which is earthed via contact sets of the "crossfeed valve" relays (e.g., /T1/RL3 for No.1 engine) and No.4 contact set of the "crossfeed switch" relay /T2/RL19.

46. The low fuel-pressure warning is repeated by the FUEL PRESS LOW lamp, on the annunciator panel, the circuit of which is connected via interconnection (3) and diode 14F/T4/MR23 to the earthing circuits of lamp CA/AT (para.44 and 45). The annunciator FUEL PRESS LOW lamp is lit and provides an additional warning

of low engine speed (less than 15% RPM) when earthed via operated contact set /T1/RL15/1; the "N_1 < 15%" relay /RL15 is energized, via interconnection (23), from a N_1 switch card in the electrical system (Part 10, Chap.1) when the speed of No.1 engine is less than 15% indicated RPM. Diode /T4/MR25 isolates contact set /T1/RL15/1 from the other earthing circuits of lamp CA/AT.

47. The circuit of the "fuel at engine 1, HP cock closed" relay 14F/T1/RL16 is arranged to provide the "steady light" and "flashing light" warnings of lamp CA/AT (para.44 and 45). A "steady light" condition is given by released contact set /RL16/2 when the coil of relay /RL16 is de-energized due to open BOOST PUMPS switch CA/AH (second section) or released contact set /T1/RL20/2 (para.40).

48. When the circuit of /RL16 is completed (CA/AH made and /T1/RL20/2 operated), a -27V supply, obtained via interconnection (32) from released contact set /RL8/1 in the circuit of the "fuel available" relay /T1/RL5 (para.38), is fed, via released contact set /RL16/1, to the relay coil. The relay is energized, after a delay given by 14G/T5/C1 and /T5/R26, and operated contact set /RL16/1 starts the "flashing" cycle. This cycle can be stopped by:

(1) Disconnecting the supply circuit to the relay coil (contact set /RL16/2 released, lamp CA/AT lit)

or by: (2) Continuously energized coil of /RL16, via diode /T1/MR36 and interconnection (40), from operated contact set /T1/RL8/1 (para.38); contact set /RL16/2 is then operated and lamp CA/AT extinguished.

49. Lamp CA/AT also flashes if any boost pump, other than No.1, is switched on and tank crossfeed is selected (para.45(2)). In this instance, the flasher relay /RL16 is earthed via operated No.3 contact sets of the "crossfeed valve" relays /T1/RL3, /T2/RL3, etc. (para.25) and via operated contact set /T2/RL19/4 of the "crossfeed switch" relay /RL19 (para.31). This condition is also fed to the circuits of LOAD meters of the electrical system (Part 10, Chap.1) via interconnections (30) and (31).

Fuel filter-clogging lamps

50. When lit, the four FUEL FILTER CLOGGING lamps SA/AD, /AE, /AF and /AG indicate a pressure differential greater than 8 lb/in^2 across the respective fuel filters; this filter-blocking condition can be introduced by the instructor's FUEL FILTER switches XF/AB/S23, /S18, /S12 and /S7 which are spring-biased to the off position. The circuits of the four FUEL FILTER CLOGGING lamps are similar and only the circuit of lamp SA/AD, associated with the No.1 fuel tank, is described.

51. Operation of the instructor's FUEL FILTER switch XF/AB/S23 energizes the "ΔP across filter > 8 psi" relay 14F/T1/RL7 which then holds via released contact set /RL7/1, provided that contact set 14E/T2/RL5/1 ("fuel heater on > 10 secs" relay, para. 53) is released. Thus, if the fuel heater is not selected, the relay will be energized.

52. Operated contact set /RL7/2 provides an earth return for lamp SA/AD which lights, being energized from the +27V supply via the FILTER CLOG circuit breaker SL/42 and contact set /T1/RL20/1 (of the "main d.c. on" relay, para. 40). If the FUEL HEATER ENG 1 & 4 switch AB/AR is set to ON, and the fuel heater valve circuit has not been failed by operation of the instructor's FUEL TEMP switch XF/AB/S24, the "fuel heater valve opened" relay 14F/T1/RL6 is energized. Operated contact set /RL6/4 actuates the circuit of the "fuel heater on > 10 secs" transistorized relay 14E/T2/RL5, (para. 53), and operated contact set /RL5/1 de-energizes relay /T1/RL7 (para. 51); contact set /RL7/2 releases and lamp SA/AD is extinguished after a delay, of approximately 10 to 15 seconds, which represents progressive clearing of the iced filter.

53. The state of the transistorized relay 14E/T2/RL5 ("fuel heater on > 10 secs") depends on the condition of relay 14F/T1/RL6 and on the No. 1 engine speed. With contact set /RL6/4 released (fuel heater valve shut), the base bias of transistor 14E/T6/TR1 is positive (from the junction of /R4 and /R5), the transistor is cut off and relay /RL5 is de-energized. When the fuel heater valve is opened (contact set /RL6/4 operated), the negative base bias of /TR1 is obtained from a N_1 switch card in the de-icing system (Part 10, Chap. 8); if the No. 1 engine speed exceeds 40% indicated RPM, the bias current, limited by /R6, is sufficient to bring /TR1 into conduction and thus energize relay /RL5. Capacitor /C1 and the associated resistors provide a 10-second delay in the operation of /RL5.

54. The state of relay 14F/T1/RL6 ("fuel heater valves opened") depends on the aircraft main d.c. busbar supplies (operated contact set 14F/T1/RL20/1, para. 40), obtained from the NO. 1 FUEL HEATER VALVES circuit breaker SH/101, and on the setting of switches AB/AR and XF/AB/S24 (para. 52). If the valve is opened (/RL6 energized and self-holding via /RL6/1), operated contact set /RL6/3 connects the +27V supply to the FUEL HEAT ON lamp SA/AH to indicate that the fuel heater is operating. When the lamp is tested for correct function (press-to-test), the lamp supplies are obtained from the FUEL HEAT ON LT circuit breaker SH/98.

55. Contact set /RL6/4 operates in the circuit of transistorized relay 14E/T2/RL5 (para. 53), and operated contact set /RL6/2 completes the de-energizing circuit for /RL6 when switch AB/AR is set to OFF (valve closed).

Air-bleed open lamp

56. The AIR BLEED OPEN lamp RD/AJ lights when the air-bleed line is opened by setting of the FUEL AIR BLEED switch RD/AH to the OPEN position. The lamp supply from the aircraft main d.c. busbar (operated contact set 14F/T1/RL20/1, para.40) is routed via the FUEL LINE BLEED circuit breaker PP/59.

FUEL FLOW SYSTEM

57. The fuel flow (FF) system computes and provides indication of the rate (in lb/h) at which fuel is fed to the respective engines. The fuel flow is proportional to the engine speed (N), aircraft height (Z), Mach number (M) and air temperature variation at a given height (δ_T) according to the equation:

$$\text{FF (in lb/h)} = 1023\ f_{22}(N)\ f_{24}(Z)\ f_{24}(M) + \delta_{FF} + \left[f_{25}(Z) + 0{\cdot}0065\ f_{23}(Z)\ \delta_T \right] 3102\ f_{23}(N)$$

Fuel flow circuit (/105)

58. The fuel flow circuit derives the signals representing the atmospheric variables and common flight parameters from the circuit of amplifier 14CF and 14CG/a which feed the individual engine N potentiometers and the fuel flow gauge drive amplifiers (e.g., 14AB/b for No.1 engine).

59. Potentiometer 13ES/RV24 feeds a positive $f_{24}(Z)$ signal to $f_{24}(M)$ potentiometer 13CS/RV24; the product is scaled via 14C/T3/R22 and is inverted by buffer amplifier 14CF which feeds the four $f_{22}(N)$ potentiometers, e.g., 14BS/RV22 for engine No.1.

60. The positive or negative δ_T signal from the instructor's O A T (outside air temperature) potentiometer XF/AM/RV4e is fed to $f_{23}(Z)$ potentiometer 13ES/RV23, the output of which is summed with the $f_{25}(Z)$ signal from potentiometer 13ES/RV25; the two signals are scaled by the respective summing resistors (14C/T3/R33 and /R32), and are amplified and inverted by buffer amplifier 14CG/a. The output of 14CG/a feeds the four $f_{23}(N)$ potentiometers (e.g., 14BS/RV23 for No.1 engine).

61. Signals corresponding to the three terms of the equation are summed at the input of No.1 engine amplifier 14AB/b, via 14A/T4/R2, /R3, and /R6; the signal supplied via /R6 represents the δ_{FF} term supplied from the instructor's FUEL FLOW potentiometer XF/AD/RV3. The four δ_{FF} potentiometers, one for each engine, enable the instructor to vary the fuel flow of any selected engine by $\pm$3000 lb/h. The lamps adjacent to the FUEL FLOW potentiometers (e.g.,

XF/AD/LP3 for engine No.1) light when the corresponding δ_{FF} potentiometer is not set to its mid-scale position and, consequently, ganged switch XF/AD/S3 supplies +27V to the lamp.

62. The second term of the equation, represented by the signal from $f_{23}(N)$ potentiometers (e.g., 14BS/RV23 for No.1 engine), is also supplied to the roll, yaw and sideforce loops (Part 8, Chap.5) as a yaw rate correction signal due to asymmetric-power flying conditions or due to asymmetric reverse thrust.

63. The FUEL FLOW GAUGE AC/BD (for engine No.1), calibrated from 0 to 4000 lb/h, consists of a 1mA moving-coil meter which is fed with the positive output of amplifier 14AB/b via diode 14A/T4/MR1, operated contact set 14F/T1/RL5/2 (when fuel is available, para.34), current-limiting resistors and a preset potentiometer which provides adjustment of the meter sensitivity and, thereby, the maximum meter deflection. The circuit of the meter is completed via circuit breaker SJ/67 to the return busbar (essential a.c.).

64. The FF signal from amplifier 14AB/b is also supplied, via interconnection (2), to the oil temperature system (Chap.6) to reduce the indicated oil temperature with increased fuel flow according to the oil temperature equation.

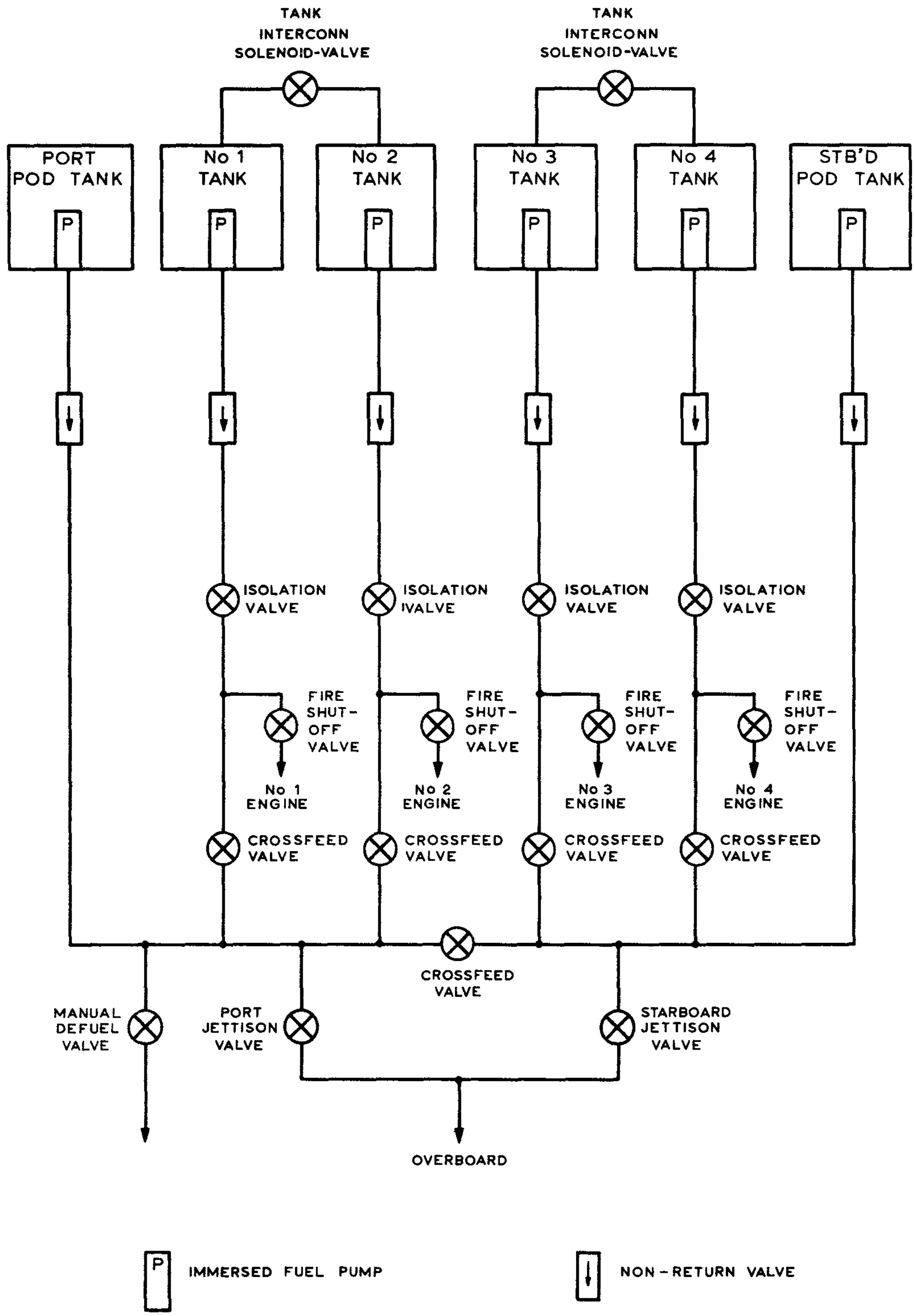


Fig 1 Simplified aircraft fuel system — diagram

Chapter 3

ENGINE STARTING SYSTEM

List of Contents

List of Illustrations

General

1. The engine starting system provides simulation of the normal engine starting procedures which are implemented in a given sequence and which result in the "engine lit" condition. The engine starting system is electrically operated and, provided that fuel and the electrical power supply are available, the selected engine is run up to a speed at which it can be ignited and maintained in the lit condition by the operation of the throttle levers. If flame-out is experienced, during flight, the windmilling engine can be started by the operation of the ignitors only. Starting faults, such as engine failure and hot-start conditions, can be simulated by the flight instructor's controls. When hot-start conditions are simulated, only the indication of the EXHAUST TEMP. gauge is affected (engine indicators systems, Chap. 6).

2. The starting controls are positioned on panel RD, on the cockpit roof, and comprise:

(1) Engine selector switch
(2) Engine START switch
(3) AIR START/NORMAL switch
(4) Battery ON/OFF switch
(5) GRD START/off/BAT START switch
(6) OPEN/CLOSE switch for the fuel bleedline
(7) AIR BLEED OPEN lamp.

The operation of the bleedline switch and lamp is not simulated.

ENGINE STARTING SYSTEM

3. The aircraft engine starters are electrically operated either from the aircraft-battery supplies or from the ground-battery supplies. The procedural engine starting sequence is:

(1) Engine No.3
(2) Engine No.1
(3) Engine No.2
(4) Engine No.4.

4. The No.3 engine is started first to ensure that the main d.c. generator can provide supplementary electrical power for starting the other engines. An engine can be lit provided that the following conditions are satisfied:

(1) D.C. power is selected
(2) Fuel is available
(3) Ground or air start is selected (as applicable)
(4) The START push-button is pressed and held operated
(5) The HP cocks are opened and the ignitors are lit by operation of the throttle lever to a position corresponding to 8·25% indicated RPM
(6) The START push-button is released when 23% indicated RPM is attained and the engine is lit
(7) The ignitors are automatically extinguished when the START push-button switch is released.

5. The starting circuits of the four engines are similar and only the No.3 engine starting circuit is described. The initial part of the starting sequence concerned with the engine speed is included in the engine speed system (Chap.4) in which the system of the RPM indicators is described.

Ground-battery start (/104, /002 and /003)

6. The electrical circuit of the ground battery selection, and of the start and ignition busbar supplies are included in the electrical system (Part 10, Chap.1). The d.c. generating system and the engine starting system are closely interlinked, and a part of the engine starting system is included on the d.c. busbar distribution system diagrams (/002 and /003).

7. Power (+27V) to the starting controls is supplied from the essential d.c. busbar, via the START circuit breaker PK/93 (/002) and released contact set 13G/T1/RL10/1 (/003) of the "start generator lock out" relay, to the engine START switch RD/AF which is armed and ready for use, provided that the other controls of the starting system are correctly set as follows:

(1) AIR START/NORMAL switch RD/AG to NORMAL
(2) Power selector switch RD/AE to GRD START position
(3) Engine selector switch RD/AC (/104) to ENG 3 position
(4) Instructor's GROUND SUPPLY switch XF/AK/S21 (/002) set to the ground supply available position.

8. The necessary "start lock in" conditions are achieved by the subsequent operation of the START switch RD/AF (/003). The essential d.c. busbar supply (+27V) is then routed, via released contact set 13G/T1/RL16/3 (/104) of the "battery series control" relay (para.16), to the throttle-lever operated microswitches (e.g., CC/AH/S1 for No.3 engine) which control the electrical circuit of the engine ignitors and HP cocks. These microswitches change-over when the respective throttle lever is set to a position corresponding to an indicated 8·25% RPM. (Drawing /104 shows the operative state of the microswitches when the throttle lever is at, or beyond, the 8·25% RPM position).

9. With the throttle lever closed, microswitch CC/AH/S1 makes, and the +27V supply is routed via pole 24 of the engine selector switch RD/AC and released contact set 14C/T1/RL7/2 of the "ignition busbar control" relay (para.18) to the "start lock in" relay 13G/T2/RL5 (/003) which energizes and self-holds via contact set /RL5/1 and the NORMAL position of switch RD/AG. Electrical power is then available via the GRD. START poles of the power selector switch RD/AE to the second section of the engine selector switch RD/AC (/104) which supplies the respective "starter on" relay 14C/T1/RL4. This relay operates provided that the "field reset" relay 14C/T1/RL13 is operated (para.25) and contact set /RL13/1 makes. The No.3 contact set of relay /RL4 operates in the engine speed system (Chap.4) where it provides a starting signal; contact set No.1 of /RL4 operates in the aircraft battery-start circuits (para.18). Relay /RL4 can also be energized from the d.c. generator emergency charging circuits (/002), via diode /MR26. The No.3 d.c. generator provides an output when the speed of engine No.3 exceeds 27·8% RPM.

10. With the throttle lever opened to a position corresponding to 10% RPM, the HP cock is opened and the ignitors are energized; the engaged starter progressively increases the engine speed and, provided that fuel is available, the engine is lit. At an indicated 8·25% RPM, microswitch CC/AH/S1 changes-over and the +27V supply is fed via the test switches of the stall warning system, AS/AJ and /AH, (lift loop, Part 8, Chap.3), the AIR START NORMAL switch RD/AG, and pole 14 of the third section of switch RD/AC, to the "No.3 ignitor" relay 14C/T1/RL17 which energizes, provided that contact sets 14C/T1/RL20/1 and 13E/T1/RL12/1 are released. When operated, contact set /RL12/1 and the stall warning switches, AS/AJ and AS/AH, prevent engine starting during pre-flight checks of the stall warning system. In the aircraft, the throttle-operated microswitches (CC/AH/S1 for No.3 engine) control the electrical circuit of the high-energy ignitors. Contact set /RL20/1 is normally released; the operated condition of /RL20 is achieved only when the fire emergency control (FIRE 3 PULL) handle is operated (hydraulic system, Part 10, Chap.2).

11. The circuits of the other three ignitor relays are similar except that the No.1 and No.4 ignitor supplies are routed directly via the respective circuit breakers, and the supply to No.2 ignitor relay can be disconnected by No.1 contact set of relay 14C/T1/RL19/1 (operated when the emergency FIRE 2 PULL handle is used) and by contact set 13G/T5/RL8/2 which is released, when the faultable No.2 ignitor circuit breaker PJ/107 is tripped (electrical system, Part 10, Chap.1).

12. The START switch RD/AF is held operated until the engine is lit and the engine speed reaches an indicated 23% RPM. The engine lit condition is achieved by operated contact set 14C/T1/RL17/1 (para.10) which connects a +27V energizing supply to the "No.3 engine lit" relay 14B/T1/RL6, provided that fuel is available (contact set 14F/T3/RL5/3 operated) and the engine is not failed by the instructor (FAIL switch XF/AF/S10/1 made). Relay /RL6 self-holds via its No.1 contact set and the relay thus stays operated after the release of the START switch RD/AF and of the "ignitor" relay /RL17.

13. When the "engine lit" relay /RL6 is operated, the ENG 3 lamp 13BS/LP6, on the state panel on rack 13, lights, and the +27V supply is routed, via interconnection (24), to slave "engine lit" relays in the exhaust gas temperature system (engine indicators systems, Chap.6) and in the thrust system (Chap.5). For test purposes, the No.3 "engine lit" relays can also be energized by operation of the ENG 3 TEST switch 13BS/S2/1 on the state panel.

<u>Aircraft battery start</u> (/104, /002 and /003)

14. The aircraft battery can be used for engine starting if ground supplies are not available. When the aircraft battery is selected for engine starting, the two batteries are series-connected, and a circuit of safety interlocks ensures that the

doubled-voltage is used for starting only. The start busbar is then isolated from the other d.c. busbars to prevent damage to circuits and components not rated for the increased voltage, e.g., lamps, motors, etc. The engine start controls must be set as follows:

(1) AIR START/NORMAL switch RD/AG (/003) to NORMAL
(2) Battery ON/OFF switch RD/AD (/002) to ON
(3) Power selector switch RD/AE (/003) to BAT START position
(4) The instructor's battery SUPPLY DOORS switch XF/AL/S8 (/002) to the doors closed position
(5) Engine selector switch RD/AC (/104) to ENG 3 position.

15. During the subsequent starting procedure, the appropriate relays of the aircraft battery start circuit are operated and the corresponding contact sets select the necessary engine start circuit conditions. "Start lock in" conditions are obtained when the START switch RD/AF is operated (/003). The +27V supply is routed, via "battery series control" released contact set 13G/T1/RL16/3 (/104) to the throttle lever operated microswitches as described in para.8; the supply is then connected via CC/AH/S1 (for No.3 engine), engine selector RD/AC and released contact set 14C/T1/RL7/2, of the "ignition busbar control" relay, to the power selection circuits. "Battery series control" relay 13G/T1/RL16 (/003) becomes energized via GRD START/ BAT START switch RD/AE and operated contact set 13G/T1/RL9/1 of the "battery doors closed" relay (/002). The circuit of relay /RL16 includes a delay network of /T1/R16 and /T26/C6 to ensure that contact set /RL16/3 (para.17) is maintained released until the supply to the coil of /RL16, via a self-holding circuit of "start lock in" relay /T2/RL5 (/003), is completed (via contact set /T2/RL5/1). Operation of the throttle microswitches and the "ignitor" relays (e.g., 14C/T1/RL17 for No.3 engine) proceeds as in the ground battery start circuit described in para.9; however, the +27V energizing supply to the "ignitor" relays is obtained via operated contact set 14C/T1/RL7/2 of the "ignition busbar control" relay (para.18).

16. When the coil of "battery series control" relay /T1/RL16 becomes energized, contact set /T1/RL16/1 (/003) subsequently connects the essential d.c. busbar supplies to the coil of "battery series" relay 13G/T1/RL15; operated contact set /T1/RL15/3 (/104) then connects the +27V supply to the second section of engine selector switch RD/AC, to the "starter on" relays (14C/T1/RL4) and to the "engine lit" relays (14B/T1/RL6) (para.12).

17. Operated contact set 13G/T1/RL16/3 (/104) energizes the coil of "battery start" slave relay 14C/T1/RL9; operated contact set /RL9/1 connects the supply from the start busbar (via interconnection (4)) to the circuit of the "ignition busbar" relays which control the battery start interlock circuits.

18. With the engine lit, the engine speed increases and the generator of the respective engine starts supplying electrical power; the respective "generator on" relay (e.g., 13G/T1/RL3 for No.3 generator, /002) becomes energized at an indicated 27·8% RPM, and operated contact set /RL3/2 supplies +27V to "generator on sensing" relay 14C/T1/RL1 (/104). Operated contact set /RL1/1 connects the +27V supply from 14C/T1/RL9/1 to "ignition busbar control" relay 14C/T1/RL7 which energizes via diode /MR29 and one of the contact sets of the "starter on" relays (e.g., 14C/T1/RL4/1) The STARTER ENGAGED lamp on the annunciator panel (Part 9, Chap.5) lights, being earthed via released contact set 13G/T1/RL10/2 of the "start lock-out" relay /RL10 (/002, electrical system), diode /T1/MR30 and operated contact set /RL4/1.

19. Contact set 14C/T1/RL1/1 also supplies +27V to the circuit of "ignition busbar transfer" relay 14C/T1/RL8 (via released contact set 14C/T1/RL6/1) and, via operated contact set 14C/T1/RL7/1 to "ignition busbar overvolt" relay 14C/T1/RL6. In the present circuit, the contact sets of these two relays, with the exception of /RL6/1, do not provide any circuit functions.

20. When the START switch is released (at engine speed exceeding 23% RPM), "battery start" slave relay 14C/T1/RL9 is released, "ignition busbar control" relay 14C/T1/RL7 is released by contact set /RL9/1, and the starting sequence can be repeated for the other engines. When all engines are lit, power selector switch RD/AE is set to the off position, and "battery series control" relay 13G/T1/RL16 and "battery series" relay 13G/T1/RL15 are both released, thus reverting the starting circuits to the original state.

Air start and automatic engine-ignition (/104)

21. Provided that a windmilling engine attains a speed of at least 8·25% RPM, and fuel and electrical power are available, the engine can be restarted by operation of the ignitors only.

22. The required circuit conditions are selected by setting AIR START/NORMAL switch RD/AG to the AIR START position, thus connecting the essential d.c. busbar supplies to the "ignitor" relays (e.g., 14C/T1/RL17) as selected by the third section of engine selector switch RD/AC. The "starter on" circuits remain de-energized and the "engine lit" condition is achieved when the "ignitor" relay contact sets operate as described in para.12, but without the use of the START switch.

23. In the AIR START position, the AIR START/NORMAL switch RD/AG also supplies +27V to the TEST switches of the stall-warning shaker system (lift loop, Part 8, Chap.3) for air-testing of the system. The necessary circuit connection is obtained via interconnection (26). During the tests of the stall-warning shaker system, operated contact set 13E/T1/RL12/1 prevents operation of the "ignitor"

relays, e.g., 14C/T1/RL17.

24. The stall warning system also provides automatic engine ignition if the aircraft approaches stall conditions at an altitude exceeding 25 000 ft. Under these conditions, "auto-ignitor" relays 13E/T1/RL9 and /RL10 are operated (in the stall warning circuit, lift loop), and either contact set /RL9/3 or /RL10/3 connects the essential d.c. busbar supplies, via diodes 13E/T1/MR21 - /MR24, to the four "ignitor" relays (14C/T1/RL15 /RL18). The circuits of the "engine lit" relays, 14A/T1/RL6, /RL17, 14B/T1/RL6 and /RL17, are thus re-energized.

Generator field reset relays (/104 and /003)

25. The "field reset" relays (e.g., 14C/T1/RL10 for No.1 engine) are connected to the control circuits of the d.c. generators (electrical system, Part 10, Chap.1). The relays are operated via switch AC/AM of the FIRE 1 PULL handle and via the RESET position of the generator FLD TRIP/RESET switch RC/AN (/003); their operated contact sets, e.g., /RL13/1 for No.3 engine, complete the circuits of the "starter on" relays (para.9).

Chapter 4

ENGINE SPEED SYSTEM

List of Contents

List of Illustrations

General

1. The speed of rotation (N) of a gas-turbine engine shaft is determined, primarily, by the quantity of fuel and air fed to the engine. The fuel flow to the engines is controlled by the four throttle levers mounted on the throttle pedestal. The volume of air, consumed by the engine, depends on the temperature and density of ambient air, on the engine compressor pressure ratio (EPR), and forward air-speed. The atmospheric variables are fed to the individual engine systems from common potentiometers which supply signals corresponding to M, q (dynamic pressure) and aircraft altitude (Z_T).

2. Each of the simulated engine speed systems comprises a summing amplifier, a power amplifier and a velodyne servo. The negative input signals are selected by contact sets of the "start" and "engine lit" relays, depending on the engine condition, and are 'balanced' against a positive positional N signal. The response of a servo is governed by the resulting voltage at the summing amplifier input and by the preset tacho-feedback loops. The constants and functions of the variables are adjusted to give a realistic servo response. The servo shaft position,

9. An additional positive or negative signal is supplied from the instructor's RPM potentiometer XF/AD/RV6 by which the engine speed of the engine No. 1 can be varied ±20 per cent (maximum) to represent a partial fault in the engine speed system. The setting of this potentiometer (δ_N) is indicated to the instructor by lamp XF/AD/LP6, which lights when the potentiometer wiper is not set to the mid-position; the segments of the integral switch XF/AD/S6 then supply the energizing voltage (+27V) to the lamp.

10. The input signals are summed with the positive signal from positional feedback N potentiometer 14BS/RV1; the signal difference is amplified by amplifier 14AE/a and applied, via 14A/T5/R10 and /R12, to velodyne drive amplifier 14AD. The circuit of amplifier 14AE/a includes a negative feedback loop of resistors 14A/T5/R8, 14BS/R2 and preset potentiometer 14BS/RV502. The output signal of the amplifier is limited by diodes 14A/T5/MR3 and /MR4 to +50V and -50V respectively.

11. Velodyne drive amplifier 14AD provides the drive for motor-tacho-generator 14BS which registers the engine speed as a shaft position. The field winding of motor 14BS/M includes a standard "limits" circuit, described in the symbols and abbreviations chapter (Part 6, Chap.1). The limits circuit ensures that the wipers of the shaft driven potentiometers cannot be moved beyond both limits of the servo scale.

12. The servo shaft drives a number of N potentiometers and the rotor of a synchro which actuates the pilot's tachometer AC/AV (for No. 1 engine); the instrument is calibrated from 0 to 110%.

13. Amplifier 14AD is shunted by the permanent negative-feedback resistor 14A/T5/R17 and tacho-generator feedback, the arrangement of which is described in para.14. The tacho-generator /G also supplies an overall negative-feedback, via preset potentiometer 14BS/RV503 and resistor 14A/T5/R9, to the input of amplifier 14AE/a to linearize the response of the servo-drive system.

14. The tacho-generator velocity-feedback loop to the input of velodyne drive amplifier 14AD is modified by the operation of contact 14A/T1/RL5/3. When the engine is unlit, released contact set /RL5/3 connects feedback resistor 14A/T5/R16 to the input of 14AD. The tacho-generator feedback voltage is preset by 14A/T5/RV501 and is varied by N potentiometer 14BS/RV2. When the engine is started, the feedback is at its maximum to represent the engine being rotated from stand-still. As the engine speed increases, the feedback voltage from /RV2 is reduced and when the "engine lit" condition is reached, contact set /RL5/3 is operated and connects resistor 14A/T5/R14 in the feedback loop. If the pilot wishes to reduce the engine speed and closes the throttle lever, the input voltages to summing amplifier 14AE/a are reduced to a less negative voltage, or to a positive voltage (depending on the speed of operation of the throttle levers and on the flight variables); consequently, the input to amplifier 14AD is reversed, the

tacho-generator feedback polarity is also reversed and one of diodes 14AT/T5/MR1 or /MR2, depending on the operative state of contact set 14A/T1/RL5/3, conducts and connects an additional resistor (14A/T5/R13 or /R15 respectively) in parallel with the appropriate tacho-generator feedback resistor in use. Thus, the gain of amplifier 14AD is reduced and the run-down time of the simulated engine turbine is increased.

Chapter 5

ENGINE THRUST SYSTEM

List of Contents

List of Illustrations

General

1. The developed thrust of a reaction engine depends on the quantity and velocity of gases passing through the jet pipe. The simulated engine thrust system is concerned with the computation of the total engine thrust from variables that are computed in other parts of the flight and engine computers. The signal corresponding to the sum of the available individual engine thrusts is fed to the drag loop system (Part 8, Chap.2) for summation with the total drag to establish the final acceleration along the line of flight.

ENGINE THRUST SYSTEM (/107)

2. The engine thrust system provides summation of the thrust components, from

the four engines, in the forward direction (against the drag forces), or, when reverse thrust is selected, in the opposite direction and with opposite polarity of the output signal. The forward thrust force signal is proportional to the engine pressure ratio (EPR). The individual EPR signals are summed into an amplifier and are corrected for Mach number (M) and aircraft height (Z) to give the total thrust. The EPR is computed in the engine pressure indicators systems, described in Chap.6. The reverse thrust signal is dependent on the aircraft forward speed (V_T), which is computed in the drag loop system (Part 8, Chap.2), and on the engine speed (N), computed in the engine speed system (Chap.4).

Forward thrust

3. The forward thrust (when the engine is lit) is computed according to the following equation:

$$\text{Thrust (per engine)} = 566\, f_{30}(M)\ (EPR - 0{\cdot}74)\ \frac{1}{f_{30}(Z)}$$

4. Amplifier 13CE/a obtains the inputs from the four engines via contact sets of the "engine lit" relays 13C/T8/RL16 to /RL19, inclusive, and of the "reverse thrust selected" relays 13C/T2/RL3, /RL8, /RL13 and /RL18. The "engine lit" relays are energized when the individual engines are started and lit. For forward thrust computation, the contact sets of the "reverse thrust" relays, e.g., 13C/T2/RL3/2, remain released. The positive EPR signal, via resistor 13C/T5/R4 (for engine No.1), is summed with a positive bias, via resistor 13C/T5/R3, the latter giving the constant of -0·74. The signals representing the four engines are summed by amplifier 13CE/a which includes, in its feedback loop, Z potentiometer 13ES/RV30. The output from the amplifier is multiplied by $f_{30}(M)$ potentiometer 13CS/RV30 which supplies the total thrust to the drag loop system.

Reverse thrust

5. Reverse thrust is proportional to forward speed (V_T) and engine speed (N). The following equation is applicable for the computation of the basic reverse thrust signal:

$$\text{Reverse thrust (per engine)} = 0{\cdot}393\ V_T\ f_{20}(N)\ f_{30}(M)\ \frac{1}{f_{30}(Z)}$$

When reverse thrust is selected, the V_T signal is supplied from the drag loop system (Part 8, Chap.2) to $f_{20}(N)$ potentiometer 14BS/RV20 (for engine No.1); the signal from the wiper of this potentiometer is fed via scaling resistor 13C/T5/R2 (engine No.1) and via operated contact sets of the "reverse thrust" selected relays which are included in the circuit of the reverse thrust hydraulics (para.7). Contact sets of the "engine lit" relays are normally operated (para.4). The summed and amplified reverse thrust signal is corrected by the circuit of amplifier 13CE/a for $f_{30}(M)$ and $\frac{1}{f_{30}(Z)}$ as described in para.4. The output of potentiometer 13CS/RV30 is fed to the drag loop.

Reverse thrust hydraulics (/108)

6. Selection of reverse thrust necessitates hydraulic power to operate the reverse thrust mechanism. The associated hydraulic system includes a number of warning and indicator lamps.

Engine No.1 circuit

7. Provided that the main d.c. busbar supply is available, via circuit breaker PN/69, operation of the engine No.1 reverse thrust control lever actuates switches CC/AF/S4 and /S3 respectively; simultaneously, the coils of the "engine No.1 in reverse" relays 13C/T2/RL1, /RL2 and /RL3 become energized via diode 13C/T1/MR1 Contact set /RL1/2 makes and hold the three relays in the energized condition; the other contact sets of the "engine No.1 in reverse" relays operate in the circuits of this system (/RL1/1 para.11, /RL1/3 para.8, /RL1/4 para.8 and /RL2/1 para.14) and in the flight and engine computers, e.g., /RL3/1 in the engine speed system, Chap.4, /RL3/2 in the selection of forward/reverse thrust component signals (para.4), /RL3/3 selects forward/reverse thrust signals in the drag loop, and /RL3/4 similarly selects forward/reverse thrust signals in the yaw loop circuit (roll, yaw and sideforce loops, Part 8, Chap.5).

8. The coils of two slave relays (13C/T2/RL4 and /RL5) are energized by contact sets No.3 and No.4 of relay 13C/T2/RL1. The coil of relay /RL5 is energized via operated contact set /RL1/4 which also supplies charging current, via operated contact set /RL5/1, to capacitor 13C/T1/C3; capacitor /C3 and resistor 13C/T1/R3 are connected across relay /RL5 to delay the release of /RL5 when contact set /RL1/4 is released. Relay /RL4 is energized, via operated contact set /RL1/3, after a delay due to the charging time of capacitor 13C/T1/C2, via released contact set /RL4/1. When the coil of relay /RL4 is energized, capacitor /C2 is discharged via resistor 13C/T1/R2.

9. Operated contact set 13C/T2/RL5/2 completes the circuit of the THRUST REV UNLOCKED lamp CB/AJ; the delayed operation of contact set /RL4/2 consequently causes the THRUST REV EXTENDED lamp AD/AG to light, thus indicating that the reverse thrust system is ready for use. Operation of the two lamps, and of the

appropriate lamps for the other engine reverse thrust systems, depends on the instantaneous operational state of contact set 14G/T26/RL16/2 which is normally made, in the warning system (Part 9, Chap.5), when the "essential d.c. and warning light" circuit breaker PJ/103 is made in the airbrakes systems (Part 10, Chap.6).

10. Contact set 13C/T2/RL4/3 supplies +27V from operated contact set /RL1/2 to the hydraulic system (Part 10, Chap.2), when released, and to the dragchute circuit of the airbrakes systems (Part 10, Chap.6), when operated. The demand on the hydraulic system, when the thrust reverse system is selected, is thus increased; operated contact set /RL4/3 ensures that, when reverse thrust system is used, the dragchute collapses.

11. When the reverse thrust system is disengaged, switches CC/AF/S4 and /S3 revert to their non-operated condition, and the potential across the "engine No.1 in reverse" relays 13C/T2/RL1, /RL2 and /RL3 is equalized, via operated contact set 13C/T2/RL1/1 and diode 13C/T1/MR2; these relay coils are de-energized, the slave relays /RL4 and /RL5 are also de-energized, and lamps AD/AG, CB/AJ extinguish. Lamp AD/AG extinguishes immediately, but lamp CB/AJ remains lit until capacitor 13C/T1/C3 discharges through resistor 13C/T1/R3 and the coil of relay 13C/T2/RL5 to earth (para.8).

Instructor's reverse-thrust fail switch

12. The instructor can operate the REVERSE thrust fail switch XF/AD/S12/1 (for No.1 engine) at any instant prior to, or during, the utilization of reverse thrust. In the first instance, the reverse thrust system will fail to operate; in the second instance, the thrust system will fail to revert to normal (forward) thrust operation. The circuit conditions are as described in para.7 to 11, inclusive.

Hydraulic pressure failure

13. Failure of the main hydraulic system pressure will necessitate the use of the reverse thrust hydraulic accumulator which normally contains enough pressure for one operation of the reverse thrust mechanism; low pressure within the accumulator is indicated by the THRUST REV PRESS LOW lamp on the annunciator panel (warning system, Part 9, Chap.5).

14. When the hydraulic pressure (of the main hydraulic system) is less than 1500 lb/in^2, relay 13F/T3/RL12 (in the hydraulic system, Part 10, Chap.2) is de-energized and arms the self-holding circuit of the "reverse thrust accumulator low pressure" relay 13C/T8/RL20. If reverse thrust of any engine is then selected, the

appropriate, operated, No.1 contact set of the "engine in reverse" relays (e.g., 13C/T2/RL2/1 for No.1 engine) completes the circuit to /RL20. Capacitor 13C/T1/C10 is discharged, thus causing a small delay, and /RL20 relay coil is energized. Operated contact set /RL20/1 now holds relay /RL20 in the energized state. Operated contact set /RL20/2, completes the circuit of the THRUST REV PRESS LOW warning lamp which lights. If, during the operation of the thrust mechanism by hydraulic pressure from the accumulator, the hydraulic pressure exceeds 1500 lb/in^2, operated contact set 13F/T3/RL12/4 disconnects the supply to de-energize relay /RL20, after a delay given by the charging time of capacitor 13C/T1/C10; the warning lamp earth connection becomes open-circuited via released contact set /RL20/2, and the relevant accumulator is fully re-charged.

Chapter 6

ENGINE INDICATORS SYSTEMS

List of Contents

List of Illustrations

Introduction

1. The engine indicators systems are concerned with the function and operation of the essential engine instruments, i.e.:

(1) engine pressure ratio (P.R.) gauge
(2) exhaust gas temperature (EXH TEMP) gauge
(3) oil pressure (OIL PRESS) indicator
(4) oil temperature (OIL TEMP.) indicator
(5) fuel flow gauge (FUEL FLOW)
(6) engine speed indicator (PERCENT RPM).

The first four indicator systems are described in this chapter; the fuel flow gauge system is included in the fuel system (Chap. 2), and the engine speed indicator and system are described in Chap. 4.

ENGINE PRESSURE RATIO INDICATOR SYSTEM

2. The engine pressure ratio (P.R.) gauge indicates the engine compressor pressure ratio which is a factor affecting the power output of the engine. The pressure ratio depends on the density and temperature of the intake air (T_1) and on the engine speed (N); the intake air, heated by compression, is also utilized for anti-icing purposes.

Engine pressure ratio indicator circuit (/102)

3. The basic equation used in the computation of the engine pressure ratio (EPR) signals is as follows:

$$\begin{aligned} EPR = {} & 7{\cdot}441\ f_{30}(N)\ f_{29}(Z)\ f_{29}(M)\left[1 - f(\delta_T)\right] - 3{\cdot}715\ f_{28}(M)\ f_{29}(N) \\ & + 3{\cdot}493\ f_{28}(N) - 1{\cdot}627\ f_{28}(Z)\ f_{27}(M)\ f_{27}(N)\left[1 - f(\delta_T)\right] + \delta_{EPR} \\ & - 5{\cdot}84 - 0{\cdot}15 \times \text{ANTI-ICING} - 0{\cdot}3 \times \text{ICING}. \end{aligned}$$

4. The atmospheric variables are supplied from Z and M potentiometers, and from the instructor's OAT potentiometer, all of which form part of the circuit common to the four engines. The engine speed (N) potentiometers are included in the individual engine EPR systems. The component signals are summed, amplified and supplied to the P.R. gauge, to the drag loop system and to the thrust system.

Common inputs

5. The signals corresponding to the first term of the equation are supplied from Z potentiometer 13ES/RV29 ($f_{29}(Z)$) which feeds M potentiometer 13CS/RV29 ($f_{29}(M)$) and buffer amplifier 14CC/a; the factor $[1 - f(\delta_T)]$ is obtained from the instructor's

OAT potentiometer XF/AM/RV4c which is connected between the output of the amplifier and wiper of 13CS/RV29. The amplifier output is fed to the individual engine N potentiometers which provide the $f_{30}(N)$ multiplier. Scaling of the first term is achieved by input resistors of amplifier 14CC/a, by negative-feedback resistor across the amplifier and by resistor 14A/T2/R2 at the output of N potentiometer 14BS/RV30.

6. The second term of the equation is represented by the signal from M potentiometer 13CS/RV28; this potentiometer supplies $f_{28}(M)$ to buffer amplifier 14CC/b which feeds the four $f_{29}(N)$ potentiometers, e.g., 14BS/RV29 for engine No.1

7. The common circuit supplying the fourth term of the equation is similar to that described in para.5 except for polarity of the energizing voltage to $f_{28}(Z)$ potentiometer 13ES/RV28. The Mach number correction is obtained via potentiometer 13CS/RV27, ($f_{27}(M)$), and the $[1 - f(\delta_T)]$ factor is supplied by the instructor's OAT potentiometer XF/AM/RV4d. Buffer amplifier 14CB inverts the product of the fourth term and feeds the four $f_{27}(N)$ potentiometers, e.g., 14BS/RV27 in the engine No.1 circuit.

Engine No.1 circuit

8. Engine No.1 circuit consists of summing amplifier 14AA which accepts the common signals and the variable signals related to the No.1 engine equation. The three common input signals are detailed in para. 5 to 7. The signal corresponding to the third term of the equation is obtained from $f_{28}(N)$ potentiometer 14BS/RV28; resistor 14A/T2/R4 provides the scaling of the signal (3·493).

9. The fifth term consists of the instructor's $\pm \delta_{EPR}$ variation (increment) of the EPR indication, provided by ENG PRESS potentiometer XF/AD/RV4 which is centre-tapped and fed with ±50V energizing voltages. Switch XF/AD/S4, which is coupled to the potentiometer shaft, supplies +27V to the adjacent lamp XF/AD/LP4 when the potentiometer is not set to the mid-scale position. Scaling resistor 14A/T2/R7, connected to +50V, supplies the constant (-5·84) which is equal to the sixth term of the equation.

10. The seventh and eighth terms represent the effect of icing, introduced by the instructor, and of selection of the anti-icing system, on the total value of the EPR signal. When the ICE switch on panel XF/AM is operated, the icing input signal is fed to the EPR system, via a delay filter-network consisting of resistors 14A/T2/R10, /R12, /R13, diode /MR1 and capacitor /C2, to represent the gradual formation of ice on the air intakes. The icing signal is finally scaled by resistor /R9. When the engine anti-icing system is selected, the coil of relay 14G/T23/RL5

in the de-icing system (Part 10, Chap. 8) is energized, and contact set /RL5/3 connects a +50V signal, via resistor 14A/T2/R8, to the summing amplifier input; this represents the partial reduction of the EPR value due to the bleeding off of the hot air for the anti-ice and de-icing systems.

P.R. gauge circuit

11. Summing amplifier 14AA accepts all the relevant signals and provides, at its output, the drives for the P.R. gauge AC/AR, and the signals to the thrust system (Chap. 5), and to the drag loop system (Part 8, Chap. 2). Only the positive output, via diode 14A/T2/MR2 and normally-operated contact set 14A/T1/RL5/1 is required for the drive and for the outgoing signals; relay /RL5 is operated when the engine is lit. The P.R. gauge is a moving-coil meter, calibrated from 1·2 to 5, and is supplied via current-limiting resistors 14A/T2/R14, /R15 and preset sensitivity-adjusting potentiometer /RV500. Capacitor 14A/T2/C1 suppresses any fast transient changes of the gauge drive signals. The earth connection to the meter is routed via normally-operated contact set 14A/T1/RL1/1 which makes if the No. 1 a.c. busbar is live, and if circuit breaker PP/32 is made.

12. The circuit of the No. 4 engine P.R. gauge includes contact set 13G/T5/RL20/2, which is operated when circuit breaker PP/35 is made and the coil of relay /RL20 (electrical system, Part 10, Chap. 1) is energized (faultable circuit breaker).

EXHAUST GAS TEMPERATURE INDICATOR SYSTEM

13. The temperature of the exhaust gases (EGT) is indicated on the EXH. TEMP gauge which is calibrated from 0 to 1000°C. The EGT depends on the intake air temperature (T_1), engine speed (N) and Mach number (M). The use of the anti-icing system also affects the EGT indication.

Exhaust gas temperature indicator circuit (/101)

14. The engine computer EGT indication is based on the following equations:

$$\text{EGT (engine unlit)} = T_1 - 273$$

$$\text{EGT (engine lit)} = 0{\cdot}33T_1 + T_1[2{\cdot}201\ f_{26}(M)\ f_{25}(N) - 0{\cdot}36] + 961\ f_{24}(N) - 273 + \delta_{EGT} + \text{ANTI-ICING} + \text{HOT START}$$

where EGT is in °C and T_1 in °K.

15. The EXH TEMP gauge AC/AZ is fed with the sum of the component signals from an amplifier which is fed with the signals corresponding to the terms of the equation via contact sets of the "engine lit" relay and the "anti-icing selected" relay.

16. Two slave "engine lit" relays 14A/T1/RL2 and /RL5 are operated by a +27V signal from the engine starting system (Chap.3). Contact sets of /RL2 are used in the circuit of the EGT system. When the engine is unlit, amplifier 14AB/a is fed with a negative T_1 signal from the outside air temperature system included in the engine computer ancillaries (Chap.7) via a resistive T-network of resistors 14A/T3/R7, /R8, /R9 and scaling resistor /R6. The second input signal represents the constant of -273 which is supplied from the +50V signal line via resistor 14A/T3/R2. Hot start simulation is introduced after the engine has been lit (para.17).

17. When the engine speed has reached the "engine lit" condition, the first of the permanently-connected input signals (para.16) is decreased in amplitude to $0{\cdot}33\ T_1$ (first term of "engine lit" equation) by operated contact set 14A/T1/RL2/3 which short-circuits resistor 14A/T3/R9. Operated contact set /RL2/4 connects the following signals to the amplifier input:

(1) Signal corresponding to the second term of the "engine lit" equation; this signal originates at the wiper of $f_{26}(M)$ potentiometer 13CS/RV26, which is fed with the $+T_1$ signal and is, together with inverting amplifier 14CA, common to all four engine circuits. The output of amplifier 14CA feeds the individual $f_{25}(N)$ potentiometers, e.g., 14BS/RV25 for engine No. 1; the wiper signal of /RV25 is summed with the $+T_1$ signal supplied via resistor 14A/T3/R14, and representing $-0{\cdot}36\ T_1$ (a part of the second term); the sum is applied to diode 14A/T3/MR2 which ensures that only the negative signal is applied to amplifier 14AB/a via resistor 14A/T3/R13.
(2) A 961 $f_{24}(N)$ signal, from potentiometer 14BS/RV24, which is scaled via resistor 14A/T3/R10.
(3) A $+\delta_{EGT}$ signal from the instructor's ENG TEMP potentiometer XF/AD/RV5 which provides ±300°C variation of the indicated EGT on the EXH TEMP gauge. When the potentiometer wiper is deflected from mid-scale position, lamp XF/AD/LP5 is lit via ganged switch XF/AD/S5.
(4) The anti-icing signal (when anti-icing is selected) via operated contact set 14G/T23/RL5/2 and scaling resistor 14A/T3/R18.
(5) The "hot start" signal which can be selected by the instructor's HOT START switch XF/AD/S11. When the switch is in the normal position, capacitor 14A/T3/C3 remains charged with -50V, via resistor 14A/T3/R5; when the switch is operated to the HOT START position, capacitor /C3 and resistor /R5 are connected, via operated contact set 14A/T1/RL2/2 (when the engine is lit), to a delay filter consisting of resistor 14A/T3/R4 and capacitor /C4, and the capacitor discharge current is applied via /R3 to the input of amplifier 14AB/a. This ensures that the amplifier input signal is temporarily

made more negative and that the EXH TEMP gauge registers an increased EGT indication.

18. The circuit of the amplifier 14AB/a includes two capacitors connected across the amplifier:

(1) Permanently connected capacitor 14A/T3/C1 and negative feedback resistor /R1.
(2) Electrolytic capacitor /C2 which has a dual purpose and effect on the EXH TEMP gauge AC/AZ reading. When the engine is extinguished, the capacitor shunts the amplifier via released contact set 14A/T1/RL2/1 and increases the output decay time; when the engine is lit, operated contact set /RL2/1 connects the capacitor to earth, thus keeping the capacitor charged up to the amplifier output voltage without affecting the transient behaviour of that voltage.

19. Only the positive polarity output of amplifier 14AB/a is passed via diode 14A/T3/MR1 to the circuit of the EXH TEMP gauge AC/AZ, via preset sensitivity potentiometer 14A/T3/RV500 and voltage dropping resistor /R19. Diode /MR1 also protects capacitor /C2 against reverse voltages. The EXH TEMP gauge is a 1mA (f.s.d.) moving-coil meter calibrated up to 1000°C. The normal EGT indication is in the range of 0°C to 700°C. When hot start is selected the temperature rises to 1000°C.

OIL PRESSURE INDICATOR SYSTEM

20. The oil pressure of each of the four engines is indicated by the respective OIL PRESS gauge; the four gauges are grouped in pairs in two containers and are operated directly by the engine oil pressure.

Oil pressure indicator circuit (/103)

21. The circuit of the simulated oil pressure system computes oil pressure signals which are directly proportional to the engine speed (N) according to the following equation:

$$P_{OIL} = 45\, f_{26}(N) + \delta_{OIL\ PRESS}$$

The sum of the negative signals representing the two terms of the equation is balanced against a positive positional feedback signal; the difference is amplified and used as drive for the oil pressure indicator servo-motor which is housed with the indicator mechanism in the instrument case.

22. The negative signals are supplied from $f_{26}(N)$ potentiometer 14BS/RV26 and from the instructor's OIL PRESS potentiometer XF/AD/RV1 which provides oil pressure variation ($\delta_{OIL\ PRESS}$) of ±50 lb/in^2; the positive positional feedback signal is obtained from the wiper of the servo actuated potentiometer AC/CC/RV1. Lamp XF/AD/LP1 is energized via ganged switch XF/AD/S1 when the OIL PRESS potentiometer is deflected from mid-position. The three input signals are summed and amplified by amplifier 14AC/b; amplifier 14A/T6 provides the drive for motor AC/CC/X1 which is coupled to the pointer of the gauge and to the positional feedback potentiometer AC/CC/RV1. The gain of the amplifiers is preset by potentiometer 14A/T4/RV501 which is in the negative feedback loop across the two amplifiers in parallel with a negative feedback via resistor 14A/T4/R12 and contact set 14A/T1/RL4/: Relay /RL4 is normally energized (para. 23 and 25), when the relevant circuit breaker is made; the amplifier feedback loop via resistor /R12 is thus open-circuited by contact set RL4/2 during normal operation of the oil pressure system.

23. The coil of relay 14A/T1/RL4 is normally energized via operated contact set 13G/T5/RL14/2; relay /RL14 is operated when circuit breaker SJ/71 (in the circuit of engine No. 1) is made, and connects electrical power to the engine No. 1 oil pressure system.

Low oil pressure indication and electrical supply failure

24. Contact set 14A/T1/RL4/1 operates in the low oil pressure indicator circuit which consists of N switch card 14BS/RV21, relay 14A/T1/RL3 and OIL PRESS LOW warning lamp mounted on the annunciator panel. When engine No. 1 is started and the engine speed, as indicated on the respective PERCENT RPM gauge, is less than 37·6%, the coil of relay /RL3 is de-energized, and released contact set /RL3/2 provides the earth connection for the OIL PRESS LOW lamp, via switch SA/AP (para. 27). When the engine speed exceeds 37·6% indicated, relay /RL3 is energized, via switch card /RV21, and the OIL PRESS LOW lamp is extinguished.

25. If circuit breaker SJ/71 is open-circuited (electrical system, Part 10, Chap. 1), coil of relay /RL4 is de-energized, and released contact set /RL4/1 arms the circuit of the "low oil-pressure" relay /RL3. When relay /RL3 operates, at an engine speed in excess of 37·6% indicated, contact set /RL3/1 completes the second energizing circuit, via contact set /RL4/1, to /RL3. This condition (open-circuited SJ/71) produces two effects on the oil pressure system:

(1) Released contact set /RL4/1 and operated contact set /RL3/1 will maintain relay /RL3 in the energized state, even if the engine speed is reduced to less than 37·6% indicated; therefore the OIL PRESS LOW lamp will not be affected by engine speed variations and will remain extinguished.

(2) Released contact set /RL4/2 connects the low-value resistor (10K) across the gauge drive amplifiers 14AC/b and 14A/T6, thus reducing the gain, so that the indicator pointer remains stationary and does not follow the engine speed (N) variations.

The normal function of the oil indicator and low oil pressure systems can be regained by resetting circuit breaker SJ/71, thus operating relay /RL4 and releasing relay /RL3.

26. The circuits of the respective circuit breakers for engines No.2, 3 and 4 are similar, but a slave relay (/RL4 for engine No.1) is not used. The operation of these circuits is identical to that of engine No.1 circuit.

27. The OIL PRESS LOW lamp on the annunciator panel is provided with four ANNUNCIATOR LT CUT OFF switches (SA/AP for engine No.1) which are in series with the No.2 contact sets of the "low oil-pressure" relays (/RL3 for engine No.1, para.25). The switches, when operated, extinguish the warning lamp in the instance of a stopped engine, or if the engine is windmilling at an indicated engine speed of less than 37·6% RPM.

OIL TEMPERATURE INDICATOR SYSTEM

28. The temperature of the engine oil is indicated on the four respective OIL TEMP. indicators which are calibrated from 25°C to 150°C. The indicators are electrically driven from temperature-detecting elements fitted in the oil system.

Oil temperature indicator circuit (/106)

29. The simulated oil temperature gauges consist of ratio-meters which are driven by signals corresponding to the terms of the following equation:

$$T_{OIL}\ (\text{in }^{o}C) = 1{\cdot}82N\ (\%) + 0{\cdot}913\ T_1\ (^{o}K) - 305 - 120\ f(FF) + \delta_{OIL\ TEMP}$$

or $$T_{OIL}\ (\text{in }^{o}C) = T_1 - 273$$

whichever is greater.

30. The signals corresponding to the terms of the first equation (for engine No.1) are summed in amplifier 14AC/a which drives the circuit of gauge AC/BW via the gating circuit of diode 14A/T4/MR2; the diode conducts only if the signal from the

amplifier is more positive than the T_1 signal routed via a second gating diode /MR3. The larger (positive) signal thus drives the gauge and the condition of the two equations is satisfied.

31. The negative component signals of the first equation consist of the following:

(1) The 1·82N signal, from the wiper of N potentiometer 14BS/RV19, which is delayed, via a network of resistors 14A/T4/R23, /R24 and capacitor /C1, to represent the gradual changes in oil temperature due to engine speed changes; the signal is scaled via resistor /R22.
(2) The 0·913 T_1 signal which is supplied from the outside air temperature system described in the engine computer ancillaries (Chap.7) and which is scaled via resistor /R25.
(3) The constant (-305) which consists of a positive bias obtained from the +50V line via scaling resistor /R26.
(4) The fuel flow signal corresponding to -120f(FF) which is supplied from the fuel system (Chap.2). The incoming positive signal from amplifier 14AB/b (in the fuel flow system) must attain a positive voltage to overcome the negative bias at the junction of resistors 14A/T4/R39 and /R38, to be passed by diode /MR4 to the delay network of resistors /R29 and /R27 and capacitor /C2. This represents the first linear portion of the FF function curve (up to 750 lb/h). At 750 lb/h the FF signal potential supplied via /R30 to diode /MR5, overcomes the positive reverse-bias at the junction of /R40 and /R32; diode /MR5 conducts and, when the FF signal increases in excess of 750 lb/h, the potential, present at the junction of /R30 and /R28, allows /MR5 to conduct more heavily and thus shape the FF curve into the third linear part of the function. The resulting FF signal, applied to the input of amplifier 14AC/a via /R28, is positive and, therefore, is subtracted from the other component signals.
(5) The $\pm \delta_{OIL\ TEMP}$ signal from the instructor's OIL TEMP potentiometer XF/AD/RV2, by which a variation of up to $\pm 100\,^{\circ}C$ can be preset to simulate faults in the oil cooling system. When the potentiometer wiper is rotated from the mid-scale position, lamp XF/AD/LP2 is supplied with +27V, via ganged switch XF/AD/S2, and lights.

32. The sum of the component signals is fed to amplifier 14AC/a and only the positive output from the amplifier is applied, via diode 14A/T4/MR2, to the transistorized circuit of the OIL TEMP. gauge AC/BW which is calibrated from $25^{\circ}C$ to $150^{\circ}C$. Diodes /MR2 and /MR3 form a gating circuit to conform to the design conditions of the two oil temperature equations (para.29 and 30). Diode /MR2 conducts if the output of amplifier 14AC/a is more positive than the (T_1 - 273) signal which is supplied via resistors /R34 and /R35 and is fed via diode /MR3 as an alternative drive for the oil temperature gauge circuit.

33. The OIL TEMP. gauge consists of a ratio-meter type of instrument which is driven with +27V via circuit breaker SJ/76, and with a variable voltage from the emitter of the drive transistor via /R44. The sensitivity of the circuit is given by the setting of potentiometer /RV502 which supplies the base of the drive transistor with a positive signal proportional to the computed oil temperature. The current through the transistor increases as the signal potential is increased, and the corresponding voltage change, at the emitter, provides the variable drive-current for the ratio-meter.

Chapter 7

ENGINE COMPUTER ANCILLARIES

List of Contents

List of Illustrations

Aircraft outside air temperature system

1. The temperature of the outside air is an important factor which affects the temperatures of the exhaust gases and of the engine oil. The ambient air temperature is detected by a sensing element positioned in the outside air stream; the measured temperature is displayed on the FREE AIR TEMP. gauge which is calibrated from $-70^{o}C$ to $+50^{o}C$.

SIMULATED OUTSIDE AIR TEMPERATURE SYSTEM (/100)

2. The simulated outside air temperature system is concerned with the computation of the outside air temperature and engine intake temperature (T_1) from functions of Mach number (M), instructor's temperature variation setting (δ_T) and aircraft height (Z) according to the following equation:

$$T\ (^{o}C) = T_1 - 273 = \frac{285\ f_{25}(M)\ f(\delta_T)}{f_{26}(Z)} - 273$$

3. A signal corresponding to the term 285 $f_{25}(M)$, is derived from M potentiometer 13CS/RV25 which is fed with -50V; when the aircraft is stationary, the M potentiometer supplies a negative voltage, from the earthy end of the potentiometer, which represents the sea-level static temperature as defined by the International Standard Atmosphere conditions (normally +15°C). The wiper voltage of /RV25 is fed to the instructor's O A T (outside air temperature) δ_T potentiometer XF/AM/RV4b by which variations of up to ±35°C can be preset. Lamp XF/AM/LP4 (not included on circuit diagram) lights when /RV4b is deflected from mid-scale setting. The signal is amplified and inverted by amplifier 14CD, the output of which is factored by negative feedback Z potentiometer 13ES/RV26 to represent the term $\frac{1}{f_{26}(Z)}$. The resulting output of 14CD corresponds to the intake temperature (T_1) which is supplied to the circuit of the FREE AIR TEMP. indicator AC/BU, to the exhaust gas temperature and the oil temperature systems (engine indicator systems, Chap.6), and to inverter-amplifier 14CE which supplies the $-T_1$ signal to these systems.

4. The circuit of the FREE AIR TEMP. indicator AC/BU is connected between the output of amplifier 14CD and earth. Voltage-dropping resistors and preset potentiometers provide adjustment of the voltage across the AC/BU indicator which consists of a moving-coil meter. To simulate a normal (ground) temperature of +15°C, the meter pointer deflection corresponds to a movement through a scale of 85°; the required current through the meter is obtained from the positive output of amplifier 14CD which is backed-off by the negative bias voltage supplied via resistor 14C/T3/R5 and preset potentiometer 14C/T3/RV501. This potentiometer, therefore, provides adjustment of the zero deflection (equal to -70°C) of the moving-coil meter. Diode 14C/T3/MR2 ensures that the meter is deflected only when a positive voltage is present at the junction of potentiometer /RV501 and resistor 14C/T3/R4. The upper limit of the meter deflection is set by potentiometer 14C/T3/RV500 and the positive voltage at the junction of /RV500 and /R4 is limited to a maximum of +27V by diode 14C/T3/MR1. The earth connection of the meter is completed via circuit breaker SG/112.

PART 8

FLIGHT COMPUTER

Chapter 1

INTRODUCTION TO FLIGHT COMPUTER

List of Contents

List of Illustrations

Introduction

1. The function of the flight computer is to compute the variable flight quantities

that determine the instantaneous flight attitude of the simulated aircraft with reference to a system of wind axes, and the aircraft position with respect to the ground or chart axes. The flight quantities are dependent on the preceding flight conditions, the setting of the instructor's controls and switches; and the setting of the pilot's and co-pilot's controls. For computation purposes, each function or condition is represented by electrical signals, or servo shaft positions, depending on the design conditions and function of each system. The computed signals actuate the relevant flight instruments, the pens of the chart recorder system, the jacks of the motion drive system, and all the appropriate indicators, warning lamps, etc. The flight simulator is shown in block schematic form in Fig.1.

2. The flight computer utilizes, as basic reference co-ordinates, a system of three wind axes (aerodynamic air-flow axes) that are based on the aircraft line of flight. The aircraft attitude, although controlled manually by the pilot, is dependent upon the aerodynamic forces and moments affecting the aircraft. Signal voltages, representing the aerodynamic forces produced by the control surfaces, are taken from potentiometers that are actuated by the controls via suitable leverage or linkage mechanisms. The controls fitted to the instructors' consoles allow variations of the atmospheric flight conditions, simulation of asymmetric flight, etc. The flight computer integrates these signal voltages and establishes the resulting aircraft attitude with respect to the wind axes and the consequent changes (if any) in the indication of the relevant flight instruments.

3. The aircraft position is computed with respect to a system of earth axes (chart axes) on to which the aircraft track and heading changes are projected and registered by the recorder pens.

4. The computation of the aircraft movements is expressed in terms of angular velocities, direction cosines, heading angles, etc., that are defined in para.5 to 31, inclusive. The terms 'positive' and 'negative', used in the definitions, do not refer to electrical potentials, but indicate the sense of direction or rotation about a datum.

Centre of gravity

5. The position of the centre of gravity (C.G.) of the aircraft depends on the empty weight (pre-determined), the amount of fuel carried, and the weight and distribution of the load carried. During normal flight, the C.G. position varies as fuel is used and the load is redistributed; to maintain longitudinal stability, the C.G. position must lie between the forward and rear limits that are defined in terms of the wing mean chord. Normally, the centre of gravity is also the origin (centre of origin) of the air-flow axes (wind axes, para.6); in the flight simulator however, the position of the centre of origin is assumed to be at the maximum rear limit of the C.G. travel, i.e., at 0·33 x wing mean chord.

Wind axes

6. The three wind axes are displaced mutually at right angles, and originate and intersect at the centre of origin (para.5). Figure 2 shows the positions of the axes during straight and level flight. The wind axes are numbered 1, 2 and 3 and their positive direction can be represented by the index, second finger and thumb of the right hand respectively. The No.1 axis is coincident with the line of flight and projects forwards and backwards from the centre of gravity; the No.2 axis is perpendicular to the No.1 axis in the horizontal plane (during straight and level flight) and it extends to port and starboard from the centre of origin; the No.3 axis is perpendicular to No.1 and No.2 axes and it extends upwards and downwards from the centre of origin. The axes are considered positive in the forward, port and upward directions. The positive sense of rotation of the three axes is the clockwise rotation when the positive axes are viewed from the centre of origin.

7. During unbanked level flight the aircraft weight acts along the No.3 axis, because under these conditions the No.3 axis coincides with the earth's vertical axis.

Note...
The No.1, 2 and 3 axes are mutually perpendicular to one another at all times, regardless of the aircraft attitude or the attitude of the axes relative to the ground.

Earth's axes

8. The earth's vertical axis is an imaginary line connecting the centre of the earth to the centre of origin of the aircraft (para.5). The effects of gravity are considered to act along this axis. The earth's horizontal plane is perpendicular to the earth's vertical axis and tangential to the earth's surface at the point of intersection of the earth's vertical axis with the earth's surface. The two mutually perpendicular axes, X and Y (Fig.3) are located in the earth's horizontal plane which, in the simulator, is represented by the charts; the X axis is parallel to the east-west, and the Y axis is parallel to the north-south, direction at the centre of the chart.

Aircraft height

9. Aircraft height is defined as the height of the centre of origin above mean sea level, and is designated Z.

Gravitational acceleration

10. The acceleration due to the earth's gravity is assumed to be a constant of $32{\cdot}18$ ft/sec^2 and is designated 'g'.

Airspeed

11. Airspeed, relative to the airflow, is considered to be along No.1 wind axis and is designated V_T.

Dynamic pressure

12. The dynamic pressure (q) is defined as $\frac{1}{2}\rho V_T^2$, where ρ_o (at sea level) is 0·00238 slugs/ft^3.

Attitude angles

13. The incidence angle (α) (Fig.3 and 4) is the angle between the No.1 wind axis and the aircraft longitudinal axis in the plane containing No.1 and No.3 wind axes.

14. The yaw angle γ (Fig.3 and 4) is the angle between the No.1 wind axis and the aircraft longitudinal axis in the plane containing No.1 and No.2 wind axes.

15. The pitch angle θ (Fig.3 and 4) is the angle between No.1 wind axis and the earth's horizontal plane.

16. The bank angle β (Fig.3) is the angle between No.2 wind axis and the earth's horizontal plane.

17. The heading angle δ (Fig.3) is the angle between the Y axis of the earth's horizontal plane and the aircraft track (the projected flight path on the horizontal plane).

18. Figure 3 shows the position of the wind axes and the attitude angles, when the aircraft is climbing and yawing to starboard, when banking to port, and the heading angle when projected onto the chart.

Direction cosines

19. Any force acting on the aircraft, e.g., weight, air-pressure, thrust, etc., can be resolved into its vectorial components acting along the wind axes. For any flight condition, other than straight and level flight, each vector force is equal to the original force multiplied by the cosine of the angle which exists between the force and the respective axis. The direction cosines define the direction of the vectorial force along the wind axes with respect to a fixed datum, i.e., the position of the earth's vertical axis. The direction cosine angles may exceed 90^o, in which instance the numerical cosine value is negative, and as a result, the vectorial force along that particular wind axis is in the negative direction.

20. Two of the direction cosines are represented by functions of $f(n_1)$ and $f(\beta)$ which are related to the No.1 and No.2 wind axes respectively. Because most of the applicable forces vectors are required in the horizontal plane, these functions are related, within certain limits, to the sines of the complementary angles.

Angular velocities (Fig.2)

21. Any change in the setting of the aircraft controls results in rotational movement of the aircraft in relation to the wind axes; if, consequently, the flight path changes, the wind axes are rotated in relation to the earth's vertical and horizontal co-ordinates

22. The rotational movement of the wind axes relative to the earth's axes is defined by the corresponding angular velocities ω_1, ω_2 and ω_3 as follows:

(1) ω_1 is the rotation of No.2 and No.3 axes about the No.1 axis; ω_1 is considered positive when the aircraft is rolling clockwise and the positive No.1 axis is viewed from the centre of origin
(2) ω_2 is the rotation of No.1 and No.3 axes about the No.2 axis; ω_2 is positive, where the aircraft is pitching clockwise about the No.2 axis and the positive No.2 axis is viewed from the centre of origin
(3) ω_3 is the angular velocity of No.1 and No.2 axes about the No.3 axis; ω_3 is considered positive when the aircraft is yawing clockwise about the No.3 axis and the positive No.3 axis is viewed from the centre of origin.

23. The angular velocities are to be considered as angular movements of the wind axes in relation to a second set of axes that do not rotate and are coincident instantaneously with the wind axes. For straight and level flight, this second set of axes is parallel to the earth's axes and the angular velocities are equal to zero. As soon as the flight path deviates from a straight line, the corresponding angular movement of the wind axes is regarded as originating from this second set of axes.

24. Rotational movement of the aircraft about the wind axes produces angular velocities about the axes, and these are complementary to the angular velocities ω_1, ω_2 and ω_3 because a change in aircraft attitude usually results in a change of the flight path. The following definitions and symbols are used:

(1) The rate of change of the incidence angle is denoted by the symbol $\dot{\alpha}$
(2) The rate of change of the yaw angle is denoted by the symbol $\dot{\gamma}$
(3) The rate of change of the aircraft heading is denoted by the symbol $\dot{\delta}$.

25. During flight, the angular motions of the aircraft axes about the wind axes, and of the wind axes about the earth's axes, occur in most instances together, and the resulting angular acceleration is equal to the sum of the two angular velocities, e.g.:

(1) $(\dot{\alpha} - \omega_2)$ is the pitch rate of the aircraft with respect to the earth's axes
(2) $(\dot{\gamma} - \omega_3)$ is the yaw rate of the aircraft with respect to the earth's axes,

Moments about the centre of gravity

26. The angular velocities of the aircraft axes (para.21 to 25, inclusive) arise as a result of the pitching, yawing and rolling moments applied to the aircraft; these moments tend to rotate the aircraft axes about the C.G. in the respective planes. Typical moments, applied to the aircraft during flight, are those produced by the movement of the control surfaces from their neutral positions (Fig.4). The sign of the moments is given by the direction of the control surface deflection which is considered positive in the following instances:

(1) Elevator deflection angle (η) is positive when the elevator trailing edge is deflected up
(2) Rudder deflection angle (ζ) is positive when the rudder trailing edge is deflected to starboard
(3) Aileron deflection angle (ϕ) is positive when the port aileron trailing edge is deflected up.

During conditions of straight and level flight, the algebraic sum of the moments in pitch, yaw and roll is equal to zero, and there are no angular accelerations or velocities along the aircraft axes. Any unbalance between the moments about one or more axes will give rise to an angular acceleration and velocity about one or more axes. The angular motions of the aircraft axes and of the wind axes with respect to the earth's axes are defined in para.25.

Aerodynamic forces

27. The basic aerodynamic forces acting parallel to the wind axes are shown in Fig.4. The thrust and drag forces that act along No.1 wind axis in conditions of straight and level flight are equal and opposite. When the aircraft is climbing or diving, the aircraft weight component will assist the deceleration due to drag or the acceleration due to the thrust respectively, and will be proportional to the function $f(n_1)$ of the pitch angle (θ).

28. The sideforces act parallel to the No.2 wind axis and arise, primarily, as a result of rudder deflection, asymmetric thrust, gusts, etc. The acceleration due to the aerodynamic sideforces is either assisted, or opposed, by the gravity component along this axis, depending on the angle of bank (β). If the sum of the sideforces does not equal zero, the resultant acceleration along the No.2 axis will produce a velocity component in the direction of the No.2 axis (V_2) which is directly proportional to the yawing force $q\gamma$.

29. The lift force acts parallel to the No.3 wind axis and is balanced by the weight component along this axis. If the sum of the forces due to lift and weight does not equal zero, the resultant acceleration along the No.3 wind axis will produce a rotation about the No.2 axis ω_2 and a pitch rate ($\dot{\alpha} - \omega_2$). Any difference between the pitch rate and the angular velocity will require the readjustment of the angle of incidence α, or the elevator trim angle η_T, to restore the balance of forces along the No.3 wind axis.

Computing loops

30. The flight computer system is based on a series of loop-circuits which resolve the basic aerodynamic data into suitable signals for all the auxiliary loop circuits. Each of the basic loops contains one or more integrating amplifiers; a "steady" state of the integrator is reached when the sum of its inputs is constant and a steady signal is maintained at the output.

Freeze switch

31. If the flight instructor decides to interrupt the flight training exercise, the simulator can be "frozen" by the operation of the "FREEZE" switch; this action will disconnect the inputs to all integrating amplifiers of the flight computer, and the computing circuits will "memorize" the previously computed signals until normal flying conditions are restored.

Master resistor

32. A "master" resistor is included in the summing network of certain computing amplifiers. This resistor is not, normally, connected to any signal source and is used for test purposes only.

State panel

33. The state panel, in position 13BS, is fitted with lamps and test switches which provide the servicing personnel with visual indication and control of the state of the flight and engine computers and of certain auxiliary aircraft systems.

34. The flight computer state is given by the following four lamps:

(1) The MAINWHEELS TOUCHDOWN and NOSEWHEEL TOUCHDOWN lamps which light when the flight computer is "groundborne".

(2) The STALL lamp, which lights when the simulated aircraft is "stalled".
(3) The FREEZE lamp which lights when the FREEZE switch is operated (para.31).

35. The following switches and lamps are related to the engine computer:

(1) The ENG lamps which indicate, when lit, that the corresponding engines are "lit".
(2) The ENG TEST switches which enable the servicing personnel to "light" the corresponding engines, thus by-passing the control circuits of the engine start system.

36. The following switches and lamps of the auxiliary aircraft systems are also fitted on the state panel:

(1) The ELECTRICS TEST switch which, when operated, energizes all the busbars of the aircraft electrical system.
(2) The busbar lamps which light when the respective busbars of the aircraft electrical system are energized.
(3) The HYDRAULICS TEST switch which, when operated, causes the aircraft hydraulic systems to become operational.
(4) The HYD lamps which light when the respective aircraft hydraulic systems are operating under normal pressures.

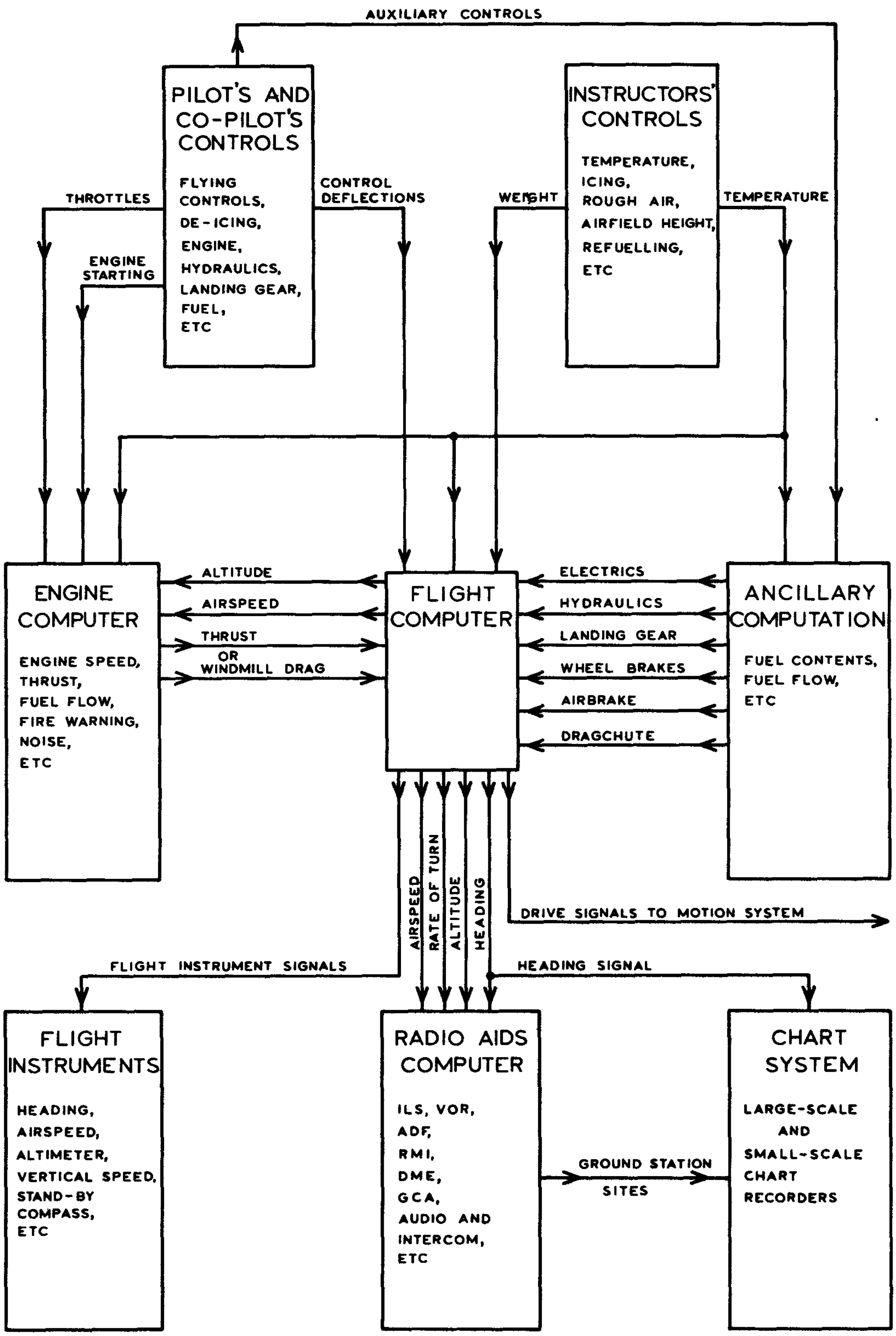


Fig.1 Flight simulator — block schematic

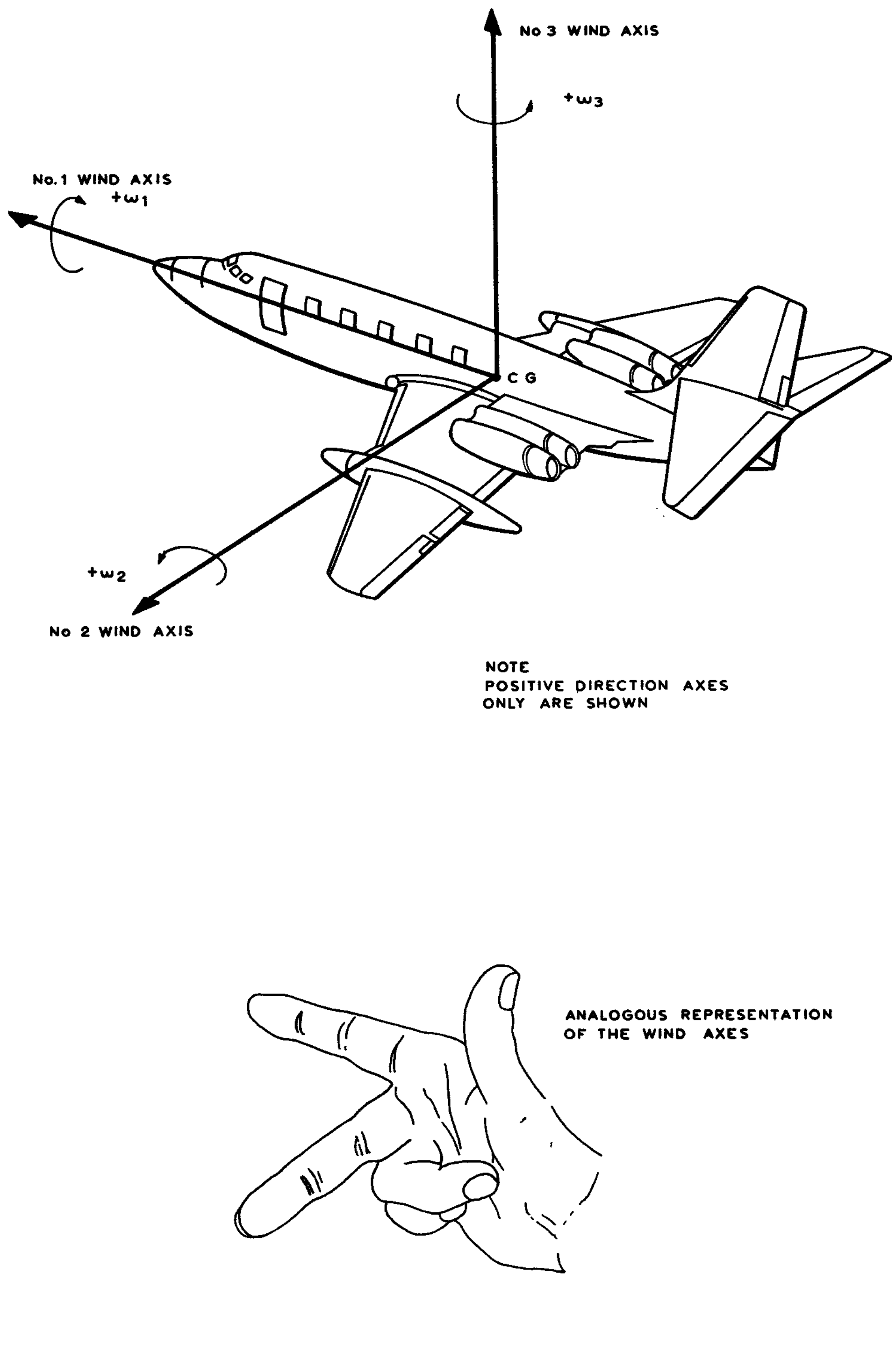


Fig 2 Simulator wind axes — diagram

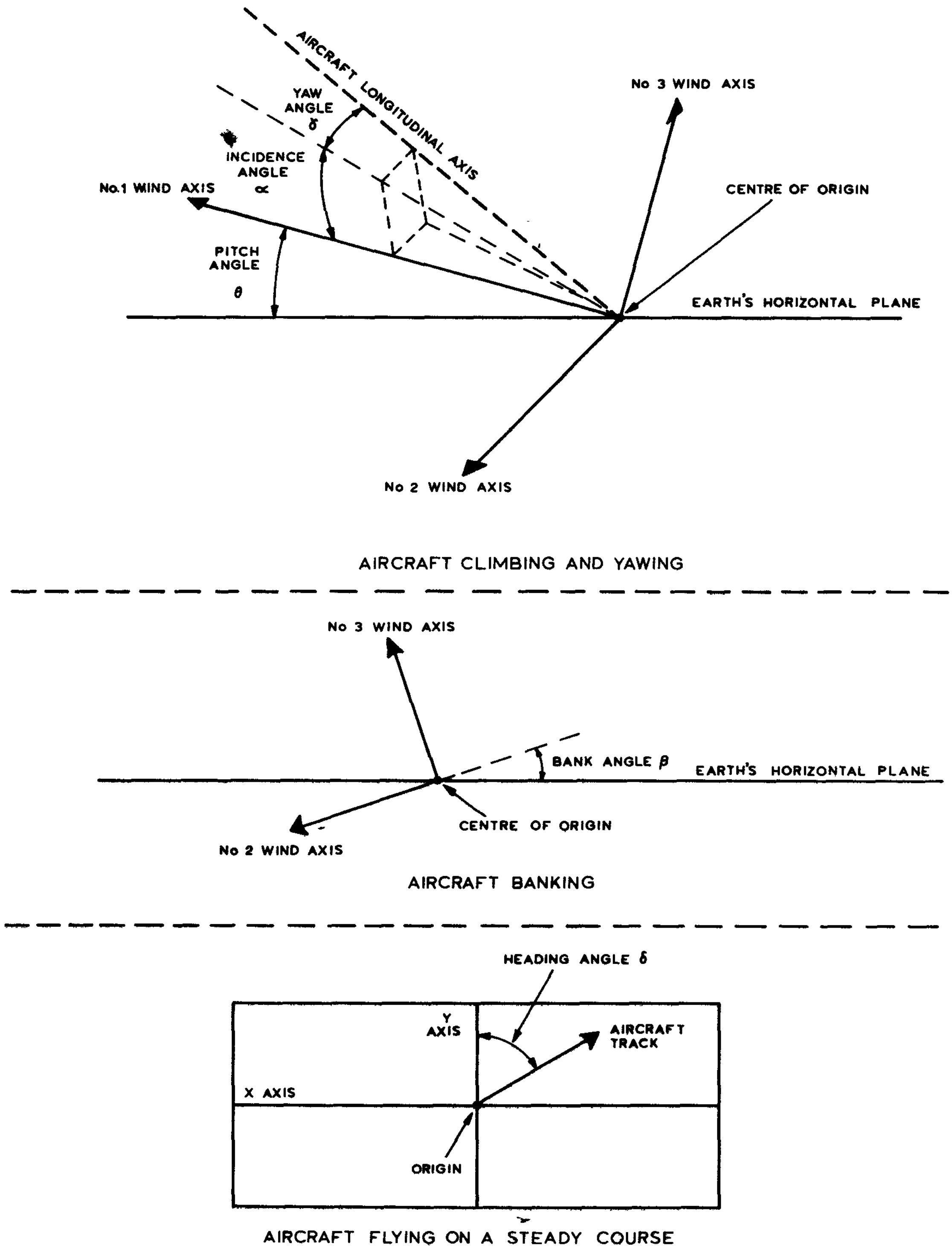


Fig 3 Attitude angles — diagrams

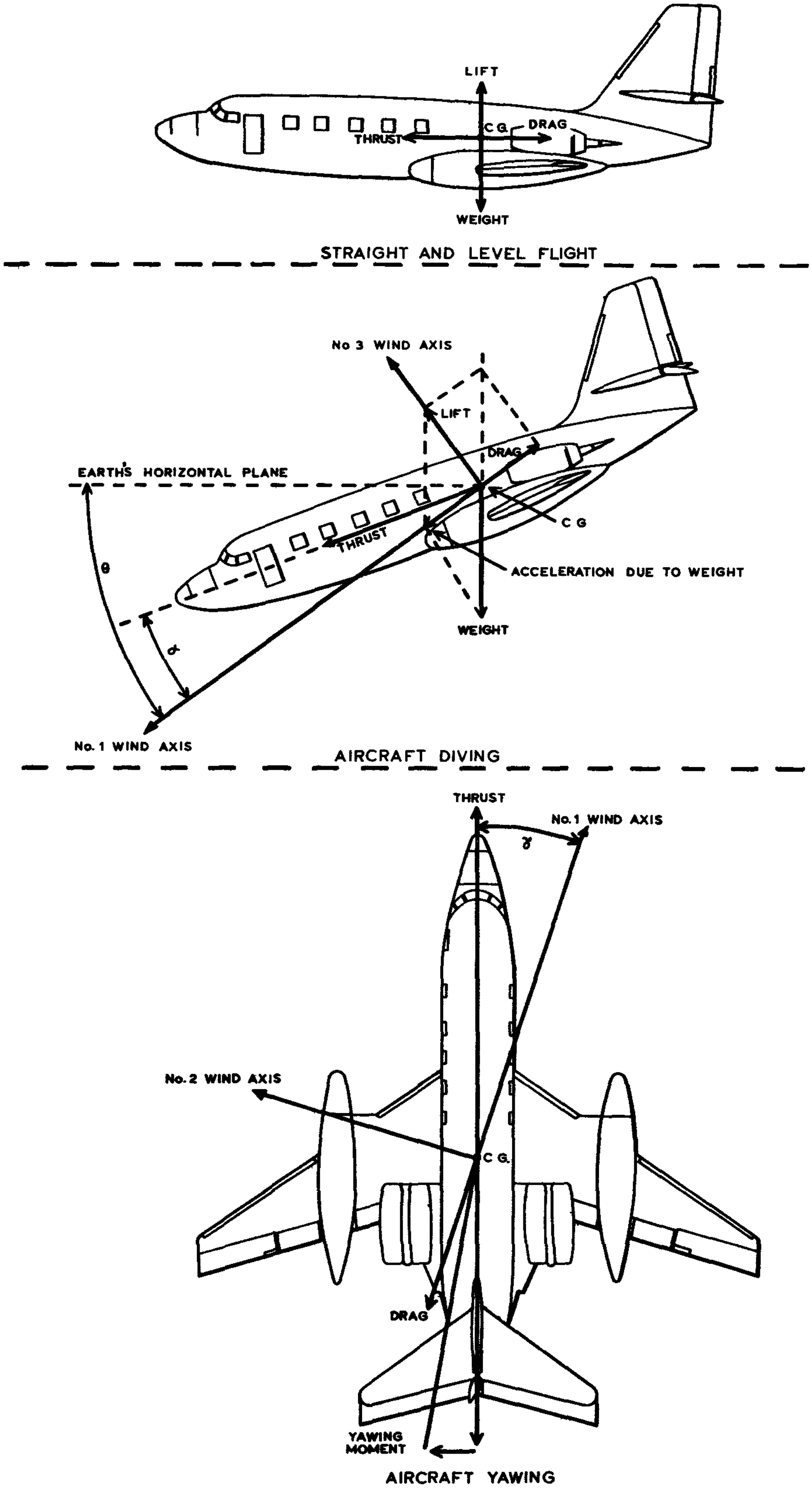


Fig. 4 Aerodynamic forces — diagrams

Chapter 2

DRAG LOOP

List of Contents

List of Illustrations

Introduction

1. The drag loop system is concerned with the computation of the motions and forces along the No.1 wind axis; these forces consist of positive (forward) force (thrust) and negative (retarding) force (drag). Any unbalance between these forces

results in acceleration or deceleration along the No. 1 wind axis; consequently, the forward speed (V_T) is re-adjusted until the balance of forces is restored.

2. The drag loop circuit accepts all the components of aircraft drag, and sums these with the thrust components which are delivered by the engines. During straight and level flight at a constant speed the total drag equals the total thrust. Higher forward speed V_T can be attained by increased thrust, or by increasing the forward force due to the gravity component (aircraft diving). Similarly, the forward speed is decreased by increased drag which is due to extended airbrakes, undercarriage, flaps, or the use of reverse thrust; when the aircraft lands, the ground friction and braking drag increase the deceleration.

3. The signals representing the various components of the aerodynamic, ground and auxiliary drag, and the signals representing the thrust developed by the engines, are summed in an amplifier, the output of which is factored by aircraft weight (W), thus producing signal $\frac{F_1}{M_T}$ which corresponds to the resulting positive or negative acceleration along the No. 1 wind axis. This signal is summed with a $-n_1 g$ signal, which represents the acceleration along the No. 1 wind axis due to the component of gravity (as corrected by the direction cosine of the relevant angle between the flight path and the earth's vertical axis). The total acceleration along the No. 1 wind axis ($\dot{V}_T$) is integrated to obtain the aircraft true speed (V_T); this signal is used in the computing loops of the flight computer, e.g., in the computation of the Mach number (M) and dynamic pressure (q) which are computed in the drag loop system according to the design equations. The computed M and q signals are registered as positions of a servo shaft which drives the wipers of a number of potentiometer or switch cards; these potentiometers and switch cards are suitably shaped to provide the various non-linear functions of the basic signals which are required for the flight computer systems.

DRAG LOOP CIRCUIT

4. The drag loop circuits are concerned with the computation of the following parameters:

(1) No. 1 wind axis acceleration $\left[\frac{F_1}{M_T} = \frac{F_1}{W} g \right]$
(2) True airspeed (V_T)
(3) Aircraft stationary condition ($V_T = 0$)
(4) Mach number (M)
(5) Dynamic pressure (q).

The five drag loop signals are generated in circuits which solve the appropriate design equations. The terms of the equations are represented by variable or fixed d.c. voltages. A schematic diagram of the drag loop circuit (Fig. 1) shows the basic drag loops circuit and the routeing of the important signals.

Acceleration along No. 1 wind axis (/208)

5. The drag and thrust summing amplifier 13CJ is fed with the sum of the drag and thrust components which represent the terms of the following equation:

$$F_1 = 73 \cdot 9\ f_{2a}(\Delta)\ q + 27 \cdot 13\ f_{12}(M)\ q - 0 \cdot 0593\ f_{2c}(\Delta)\ L$$

$$+ 0 \cdot 1521\ f_{2e}(W)\ f_{13}(Z)\ f_{14}(M)\ L$$

$$+ \frac{2 \cdot 076\ W}{f_3(q)\ 10^6} \left\{ 0 \cdot 0873\ K_1\ f_{2b}(\Delta) + f_{13}(M) \right\} L$$

$$- \left\{ \Sigma TH + K_8\ f(Z) - K_8\ f_{27}(Z) \right\}$$

$$+ K_2 \left\{ K_6\ q + K_7\ L \right\} + A.B.\ 6 \cdot 5\ f_{18}(M)\ q$$

$$+ K_4\ BRAKES + K_5\ 200\ q + ICING + GUSTS$$

where K_1	=	$0 \cdot 56$	(groundborne)
	=	$1 \cdot 0$	(airborne)
K_2	=	0	(undercarriage up)
	=	$1 \cdot 0$	(undercarriage down)
K_4	=	0	(airborne)
	=	$1 \cdot 0$	(groundborne)
K_5	=	$1 \cdot 0$	(dragchute streaming)
K_6	=	$4 \cdot 54$	(undercarriage doors closed)
	=	$7 \cdot 59$	(undercarriage doors open)
K_7	=	$0 \cdot 0085$	(undercarriage doors closed)
	=	$0 \cdot 0055$	(undercarriage doors open)
K_8	=	11 035/engine	(engine "lit" conditions - forward thrust only).

6. The drag and thrust components include the basic profile aircraft drag, drag due to extended flaps, compressibility drag increment, and auxiliary drag components, e.g., braking dragchute, airbrakes, icing drag, etc. The following components constitute the force F_1:

(1) Aircraft profile drag (at zero lift) corrected for flap deflection angle (Δ). The corresponding signal, which is proportional to the first term of the equation ($73 \cdot 9 \ f_{2a}(\Delta) \ q$), consists of the q-corrected potential from the wiper of potentiometer 13AS/a/RV2; the shape (f_{2a}) of this potentiometer is such that the drag signal is increased at larger angles of flaps.

(2) Compressibility drag increment (at zero lift) which is dependent on the numerical value of Mach number (M); the corresponding signal is proportional to the second term of the equation ($27 \cdot 13 \ f_{12}(M) \ q$) and is supplied by the wiper of q-fed M potentiometer 13CS/RV12. The numerical value of this signal is increased at higher Mach number to simulate the effects of compressibility.

(3) An additional aircraft profile drag correction which is dependent on the developed lift (aircraft attitude) as given by the third term of the equation ($- 0 \cdot 0593 \ f_{2c}(\Delta) \ L$). The corresponding signal is supplied by Δ potentiometer 13AS/a/RV2c which is fed with the L signal from the lift loop (Chap. 3); the numerical value of the signal is increased at higher angles of flap deflection.

(4) Induced drag which depends on the developed lift L at height Z, Mach number M and aircraft weight W. The corresponding signal is proportional to the fourth term of the equation ($0 \cdot 1521 \ f_{2e}(W) \ f_{13}(Z) \ f_{14}(M) \ L$) and is obtained from inverter-amplifier 13CH/a which is fed with the product of L W and M from potentiometers XF/AM/RV2e (set by the instructor) and 13CS/RV14. The $f_{13}(Z)$ correction is obtained by routeing the output signal of amplifier 13CH/a via Z potentiometer 13AS/RV13.

(5) Drag due to the variation of coefficient of lift which is proportional to $\frac{L}{q}$ product and which includes corrections due to aircraft weight W, angle of flap deflection Δ and Mach number M. The signal corresponds to the $\left(\frac{2 \cdot 076 \ W}{f_3(q) \ 10^6} \left\{ 0 \cdot 0873 \ K_1 \ f_{2b}(\Delta) + f_{13}(M) \right\} L \right)$ term of the equation. The M and Δ signals from L-fed potentiometers 13CS/RV13 and 13AS/a/RV2b, respectively, are added at the input of amplifier 13CH/b; the sum is factored by q potentiometer 13DS/RV3 and corrected by the instructor's W potentiometer XF/AM/RV2d. The component is corrected for the undercarriage up or down condition by contact set 13C/T8/RL2/2 which makes and short-circuits resistor 13C/T7/R16 when the aircraft touches down and relay /RL2, in the roll, yaw and sideforce loops (Chap. 5), is energized by a signal from the height and touchdown system (Chap. 7); this undercarriage correction represents the decreased effect of flaps on the ground.

(6) Total thrust force which, in flight, is a positive, drag-opposing force, or which constitutes a drag component if the engines are windmilling or supplying reverse thrust. The forward thrust signals are corrected for height Z, the reverse thrust signals are proportional to the engine pressure ratio (EPR), and in the instance of an "unlit" engine, the windmilling drag signal is proportional to dynamic pressure q. The corresponding term of the equation consists of $-\left\{ \Sigma TH + K_8 f(Z) - K_8 f_{27}(Z) \right\}$. The signals representing the three engine thrust conditions are computed as follows:

(a) When the engines are supplying thrust, the sum of engine thrust (ΣTH) is fed via interconnection (19) from the thrust system (Part 7, Chap. 5) where the necessary thrust corrections for Mach number (M) and height (Z) have been made. The additional Z correction ($K_8 f(Z) - K_8 f_{27}(Z)$) is provided by potentiometer 13ES/RV27 which supplies a signal via the four respective scaling resistors (e.g., 13C/T7/R32 for engine No. 1), released contact sets of the "reverse thrust selected" relays (e.g., 13C/T2/RL3/3) which are included in the engine thrust system (Part 7, Chap. 5), and operated contact sets of the "engine lit" relays (e.g., 13C/T8/RL16/1) in the engine thrust system, to the drag force summing amplifier input.

(b) When the engines are delivering reverse thrust, contact sets of the "reverse thrust selected" relays, in the engine thrust system (Part 7, Chap. 5), are operated, and the reverse thrust drag force is proportional to the engine pressure ratio (EPR) signals supplied by the engine pressure ratio indicator system (Part 7, Chap. 6).

(c) When engine windmilling conditions are simulated, the windmilling drag force is proportional to dynamic pressure q supplied via interconnection (21) from amplifier 13BB (para. 22); the drag signal is reduced in amplitude by potential-divider network 13C/T7/R39 and /R40. The contact sets of the "engine lit" relays, in the engine thrust system (Part 7, Chap. 5), (e.g., 13C/T8/RL16/1) are then released.

(7) Undercarriage profile drag which is added when the undercarriage is extended. The corresponding signal is proportional to the term $K_2 \left\{ K_6 q + K_7 L \right\}$. The q and L signals are supplied via interconnection (10) from amplifier 13BB (para. 21) and via interconnection (20) from the lift loop (Chap. 3), respectively. Two undercarriage conditions are simulated:

(a) The main undercarriage down condition (operated contact set 13C/T8/RL3/1)

(b) Undercarriage door position:

(i) undercarriage in transit, doors opened
(operated contact set 13C/T8/RL4/1)

(ii) undercarriage fully down, doors closed
(released contact set 13C/T8/RL4/1).

The q-dependent signal, from the junction of resistors 13C/T6/R17 and /R19, is summed with the L-dependent signal, from the junction of resistors /R22 and /R24, and, when the undercarriage is lowered, the "u/c down" relay 13C/T8/RL3 is operated by a signal from the landing gear system (Part 10, Chap.3) via interconnection (22); operated contact set /RL3/1 then connects the summed undercarriage drag signal to the input amplifier 13CJ. The variation of undercarriage drag due to the opened undercarriage doors, is simulated by operated contact set 13C/T8/RL4/1 which reduces the amplitude of the L signal (by short-circuiting resistor /R20) and increases the q signal (by open-circuiting /R25). When the undercarriage doors close, contact set /RL4/1 is released and the respective amplitudes of the q and L signals revert to the original values. When the undercarriage is being retracted, the undercarriage drag signal is removed by released contact set 13C/T8/RL3/1.

(8) Airbrake drag which increases the drag force when the airbrakes are extended. In this instance, a signal from the airbrakes system (Part 10, Chap.6) is applied to a tap on M potentiometer 13CS/RV18; the wiper of /RV18 feeds q potentiometer 13DS/RV10 from which the airbrakes drag signal is obtained. This signal is proportional to the term: $A.B.\ 6{\cdot}5\ f_{18}(M)\,q$.

(9) Ground-friction drag due to the application of the wheel brakes. Signals from the starboard and port pedal-operated potentiometers, in the wheel brakes system (Part 10, Chap.4), are applied via interconnections (17) and (16), respectively, and represent the term: K_4 BRAKES. The signals are connected to the summing amplifier input via contact sets 13C/T8/RL1/4 and /RL2/1 which operate when the simulated aircraft touches down. The respective relays are included in the roll, yaw and sideforce loops (Chap.5).

(10) Drag due to the streaming of the braking dragchute. The corresponding signal represents the term (K_5 200 q). The q signal, from amplifier 13BB (para.22) is supplied via interconnection (18) and contact set 14G/T26/RL12/2 to the drag summing amplifier. Relay /RL12 operates when the pilot jettisons the dragchute (airbrakes systems, Part 10, Chap.6).

(11) Drag due to the simulated icing conditions. The corresponding signal is proportional to the q signal which is applied, via the "de-icing selected" contact set 14G/T24/RL1/1 and via operated "ice present" contact set 14G/T23/RL14/2, to a delay circuit 13C/T6/R4 and /C1. The "ice present"

conditions are introduced by the instructor (de-icing system, Part 10, Chap.8), and the time constant (approximately 10 seconds) of the delay circuit provides simulation of gradual ice formation. When contact set /T23/RL14/2 operates, the q signal charges capacitor /C1 via /R4. The gradually-rising icing signal is fed to the drag summing amplifier and to the lift summing amplifier (lift loop, Chap.3). When the de-icing system is selected (Part 10, Chap.8), operated contact set /T24/RL1/1 disconnects the q signal, and capacitor /C1 discharges via summing resistor /R2. The icing signal is thus progressively removed.

(12) Drag variation due to encountered air gusts; the gust signal is connected to the drag summing circuits via interconnection (15) when the instructor selects the desired percentage of total available air turbulence (Part 9, Chap.4). This irregular signal produces typical buffeting effects on the aircraft drag, lift, sideforce, etc.

(13) The effects of stall are simulated by the connection, via operated contact set 13E/T1/RL16/4, of the $-n_1$ signal from the direction cosine system (Chap.6). Relay /RL16 is operated at the moment of stall in the lift loop system (Chap.3).

7. The sum of the thrust and drag forces is inverted by amplifier 13CJ and factored by the W signal from the variable feedback W potentiometer XF/AM/RV2b which is set by the instructor to the estimated aircraft weight. The resulting acceleration $\left(\frac{F_1}{M_T}\right)$ signal is supplied to the V_T computing amplifier 13BA (para.10) and to the motion drive system (Part 4, Chap.2).

8. Included on drawing /208 are the "undercarriage down" relay 13C/T8/RL3 and "undercarriage doors open" relay /T8/RL4. The relay coils are energized when the appropriate signals from the landing gear system (Part 10, Chap.3) are obtained. The contact sets of these relays switch the undercarriage drag to the input of amplifier 13CJ (para.6(7)).

Aircraft speed V_T (/201)

9. The aircraft true airspeed (V_T) is computed by integration of the accelerations or decelerations along the No.1 wind axis according to the equation:

$$V_T = \int_0^t \left(\frac{F_1}{M_T} - n_1 g - 0{\cdot}8 \text{ T.D.} - 45{\cdot}8 \text{ CRASH} \right) dt$$

10. The four terms of the equation are represented by four inputs to the integrating amplifier 13BA:

(1) $\frac{F_1}{M_T}$ acceleration produced at the output of amplifier 13CJ (para.7)

(2) $n_1 g$ signal computed in the direction cosine system (Chap.6)

(3) The retarding ground-friction signal which is proportional to (- 0·8 T.D.) term and which is connected via operated contact set 13A/T1/RL5/2 when the mainwheels are on the ground (height and touchdown system, Chap.7)

(4) The crash signal, connected via operated contact set 13B/T1/RL5/1, when "crash" conditions are simulated (para.11).

11. The input signals are summed and applied to integrating amplifier 13BA via normally-released contact set 13B/T1/RL1/1 of the "freeze" relay which is operated in the roll, yaw and sideforce loops system (Chap.8) by the instructor's FREEZE switch (Chap.1). The coil of the "crash" relay 13B/T1/RL5 can be energized when the instructor decides that the forthcoming landing would result in a crash landing; with CRASH switch XF/AM/S6 closed, the coil of the "crash" relay is energized when contact set 13A/T1/RL5/3 of the "touchdown" relay (height and touchdown system, Chap.7) is operated at the point of touchdown. The crash signal produces a rapid deceleration.

12. The circuit of amplifier 13BA includes integrating capacitor 13B/T2/C1 and negative feedback loop consisting of 13B/T3/R25 and /MR24; the loop is completed by contact set 13B/T1/RL4/1 which is released when the "V_T = 0" discriminator releases relay /T1/RL4 (para.14). The function of diode /MR24 is to prevent the $-V_T$ signal becoming positive, when large negative inputs (crash and touchdown signals) are switched into the amplifier input circuit.

13. The output of amplifier 13BA constitutes the $-V_T$ signal which is fed via interconnection (5) to the flight and engine computer systems and, in the drag loop, to the circuits of M-servo, "V_T = 0" discriminator and to the q-signal generating circuits.

Zero-speed discriminator (/201)

14. The function of the zero-speed discriminator is to provide "locking" of the flight simulator when the simulated aircraft is groundborne and stationary. The "$V_T \neq 0$" relay 13B/T1/RL4 is released when the computed airspeed is approximately zero. The contact sets of /RL4 operate in the following circuits:

(1) Contact set /RL4/1 operates in the feedback loop of amplifier 13BA (para.12)

(2) Contact set /RL4/2 provides, at zero airspeed, increased damping of the yaw response in the roll, yaw and sideforce loops system (Chap.5)

(3) Contact set /RL4/3 operates in the motion drive system (Part 4, Chap.2)

(4) Contact set /RL4/4 provides locking of the chart recorder pens at zero airspeed.

15. The discriminator circuit consists of high-gain amplifier 13BF/a which is fed with the $-V_T$ signal. For 'normal' ranges of airspeeds the V_T signal is amplified sufficiently to ensure that relay coil 13B/T1/RL4 is energized via diode 13B/T4/MR2. A second diode, /MR1, biased by the potential appearing at the junction of resistors /R25 and /26, limits the positive output of amplifier 13BF/a to approximately 110V. With small V_T input signals, the amplifier gain, due to partial negative feedback via 13B/T4/R21, is high and a large positive output voltage is obtained.

Mach number servo (/201)

16. The Mach number M is computed by solving the following design equation:

$$M = 0{\cdot}001034 \ V_T \ f_2(Z) \ f_{4a}(\delta_T)$$

The computed M signal provides a drive for the M servo which registers the Mach number as a shaft position.

17. The $-V_T$ signal from amplifier 13BA (para.13) is multiplied by $f_2(Z)$ and $f_{4a}(\delta_T)$ via potentiometers 13ES/RV2 and XF/AM/RV4a, respectively; the resulting negative product is summed with a positive signal from positional M potentiometer 13CS/RV1 and is applied via released contact set 13B/T1/RL2/1 of the "M manual selected" relay /RL2 to the servo drive amplifier 13BE. Relay coil /RL2 is energized only during manual resetting of the M servo shaft when switch 13CS/S1 is set to the MANUAL position; normally the switch is set to AUTO.

18. The gain of the M servo drive amplifier 13BE is preset by potentiometer 13CS/RV502; velocity feedback is set by 13CS/RV503. The M servo drives a number of M potentiometers which supply the various functions of M to the flight and engine computers.

19. The output of δ_T potentiometer XF/AM/RV4a is also supplied, via interconnection (7), to the Machmeter gauge (Part 11, Chap.1); the output of the positional M potentiometer 13CS/RV1 is available for external circuits via interconnection (6).

Dynamic pressure computation (/201)

20. The dynamic pressure q is computed by solving the following equation:

$$q = 1{\cdot}372 \ V_T \ M \ f_3(Z) \left[1 + f_{4f}(\delta_T) \right]$$

The resolved +q signal is supplied to various flight computer systems, to an inverter stage which produces the -q signal, and to the q servo drive amplifier. The q servo shaft drives the q potentiometers which supply the various q-functions to the appropriate computing circuits.

21. The $-V_T$ signal from amplifier 13BA (para.13) is fed via potentiometers 13CS/RV6 and 13ES/RV3 for multiplication by $f_6(M)$ and $f_3(Z)$, respectively. The computed q signal is applied to the input of amplifier 13BB via released contact set 13B/T1/RL3/2 of the "q manual selected" relay /RL3; the coil of this relay is energized only during manual resetting of the q servo shaft (para.25), when switch 13DS/S1 is set to the MANUAL position. In this instance, the computed q input to amplifier 13BB is removed and replaced by the output of the q positional potentiometer 13DS/RV1 (para.25) to ensure that the +q signal is maintained proportional to the indicated q value on the servo scale.

22. The output of amplifier 13BB is applied to high-power cathode-follower unit 13B/T7 which is capable of supplying the +q signal to the numerous systems supplied via interconnection (3) and detailed on drawing /201. Description of the higher-power cathode-follower unit is given in para.27 to 36 inclusive. The +q signal is also fed via interconnection (12) to the "$+q > 800$ lb/ft^2" relay 13B/T1/RL6 which operates when the level of the +q signal exceeds this limit. Operated contact set /RL6/1 then disconnects the +q signal output of 13B/T7 to protect the +q-supplied circuits from excessive voltages.

23. The -q signal is produced in the inverter stages consisting of amplifier 13BC and high-power cathode-follower unit 13B/T8 (para.27). The -q signal is supplied, via interconnection (4), to the various systems which are protected by contact set 13B/T1/RL7/1 against excessive levels of the -q signal by the "$-q > 800$ lb/ft^2" relay 13B/T1/RL7 the operation of which is similar to that of relay /RL6 (para.22).

24. The +q and -q signals are corrected by the instructor for outside air temperature (OAT) variation (δ_T); this correction is obtained from potentiometer XF/AM/RV4f which is fed with the positive and negative computed q signals. The signal from the wiper of this potentiometer thus provides the positive or negative correction $f_{4f}(\delta_T)$, fed to amplifier 13BB via 13B/T3/R3.

Dynamic pressure servo

25. The sum of the +q signal, from the power stage 13B/T7, and of the q positional potentiometer 13DS/RV1 is fed to the servo-drive amplifier 13BD via released contact set 13B/T1/RL3/1 of the "q manual selected" relay (/RL3); relay coil /RL3 is energized only during manual resetting of the q servo shaft, when switch 13DS/S1 is set to the MANUAL position (para.21). This circuit arrangement ensures that the computed +q and -q signals are in step with the servo scale during manual resetting of the q servo.

26. The gain of the q servo-drive amplifier 13BD is preset by potentiometer 13DS/RV502; velocity feedback is set by potentiometer 13DS/RV503.

HIGH-POWER CATHODE-FOLLOWER UNIT

27. The high-power cathode-follower unit is specially designed to provide a high-current, low-impedance output at an overall gain of unity. The circuit of the unit consists of an input stage which feeds three, parallel connected, power-output stages.

Circuit description (C218699/01)

28. The high-impedance input signal, from PL1/10, is routed, via potentiometer RV1 and R10, to the grid of pentode V1 (6CH6) which is triode-connected. Potentiometer RV1 is provided for zero-output (at zero-input) adjustments of the unit (para.34).

29. The signal output from the anode of V1 is fed to the grids of V2, V3 and V4 (6CH6) via potential-divider network R12 and R8, and via the respective grid-stopper resistors R21, R23 and R25. The voltage at the junction of R12 and R8 establishes the operating point of the three lower valves of the output pairs, V2, V3 and V4. Filter R20 and C1 improves the h.f. stability of the circuit. The upper valves of the output pairs, V5, V6 and V7 (E2134) are self-biased via the respective grid-stopper resistors R14, R16 and R18 from the junction of load resistor R3 and R22, R24, R26.

Power supply requirements

30. The following power supplies are required by the high-power cathode-follower unit:

(1) 6·3V a.c. (earth level) - 2·67A
(2) 6·3V a.c. (-300V level) - 2·25A
(3) +300V d.c. - 200mA
(4) -300V d.c. - 200mA
(5) -500V d.c. - 150 μA.

Performance details

31. The maximum power output of the high-power cathode-follower unit, when operating into an external load of 600 ohms, is 15 watts.

Test procedure

32. The following test procedure includes stability checks, and tests of the power output amplitude and residual hum level. The following test equipment is required:

(1) Oscilloscope

(2) D.C. valve voltmeter

(3) One 600-ohm, 25-watt load resistor

(4) Two 1-megohm, $\pm$1 per cent, resistors

(5) One 150-kilohm, $\pm$1 per cent, resistor

(6) One 100-kilohm, $\pm$1 per cent, resistor

(7) One 47-kilohm, $\pm$1 per cent, resistor

(8) Three single-pole, change-over switches

(9) One type DE amplifier (pre-tested and zeroed).

33. Connect the required power supplies to the high-power cathode-follower unit and to the DE amplifier, and allow at least 3 minutes before switching on the h.t. supplies.

Zeroing and hum-level tests

34. Connect the high-power cathode-follower and the type DE amplifier as shown in the test circuit (Fig.2). Set the DE amplifier zero/compute switch to the compute position (for all tests), set S2 (in the test circuit) to the off position, and adjust preset potentiometer RV1 (on the high-power cathode-follower) to reduce the output, indicated on the valve voltmeter, to zero volts. Check that the residual hum level, as displayed on the oscilloscope, is not greater than 25mV peak-to-peak.

Output voltage checks

35. Set switch S1 (in the test circuit) to the +300V position, switch S2 to the on position and switch S3 to the 100V position. Check that the high-power cathode-follower output is approximately +100V. Repeat this check with the test switch S1 set to the -300V position and check that the output is -100V.

36. Set switch S3 (in the test circuit) to the 150V position and check that the output of the high-power cathode-follower is not less than -110V. The overload indicator on the DE amplifier should now be lit. Repeat this check with the test circuit switch S1 set to the +300V position; check that the output is not less than +110V.

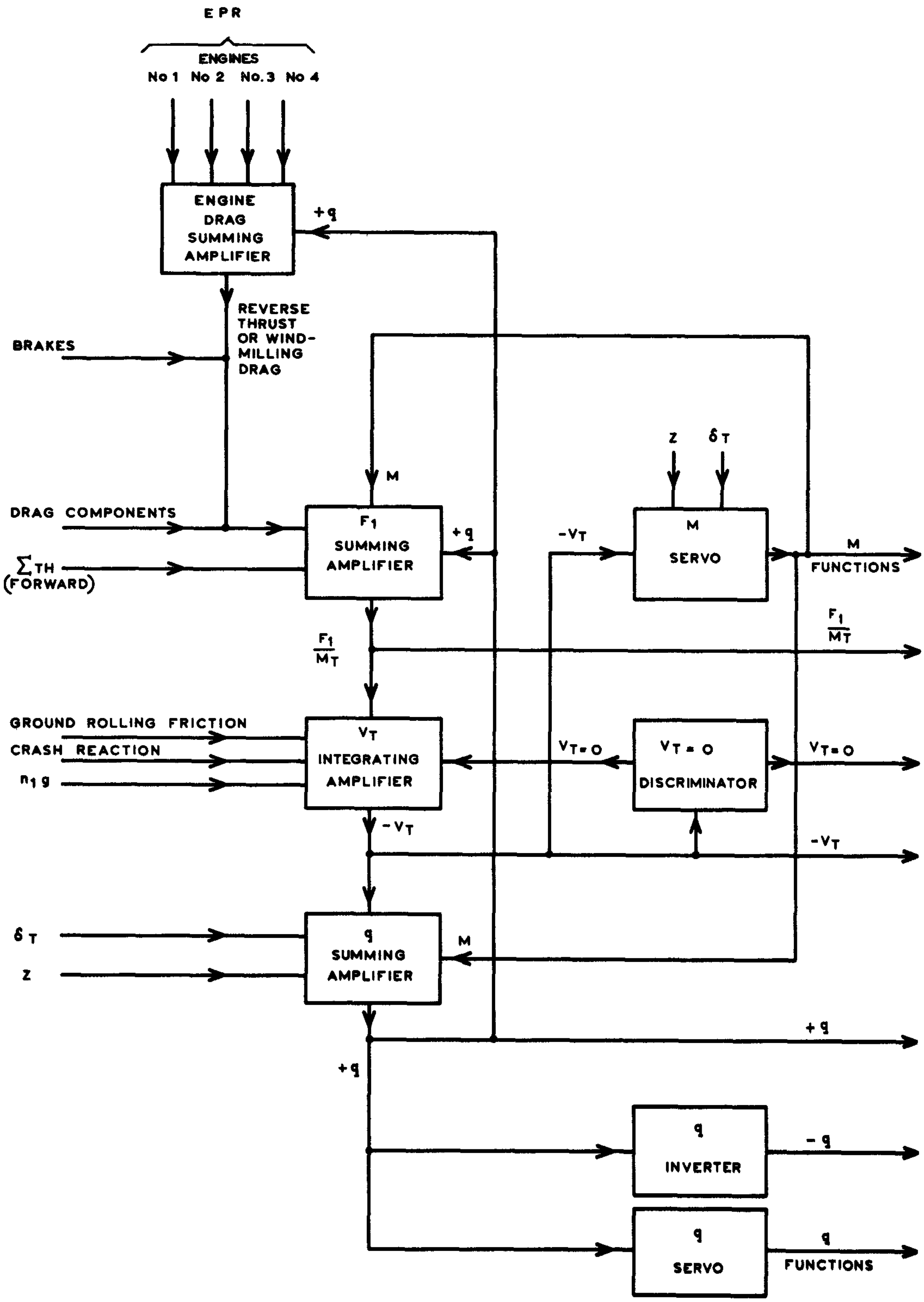


Fig.1 Drag loop system – schematic diagram

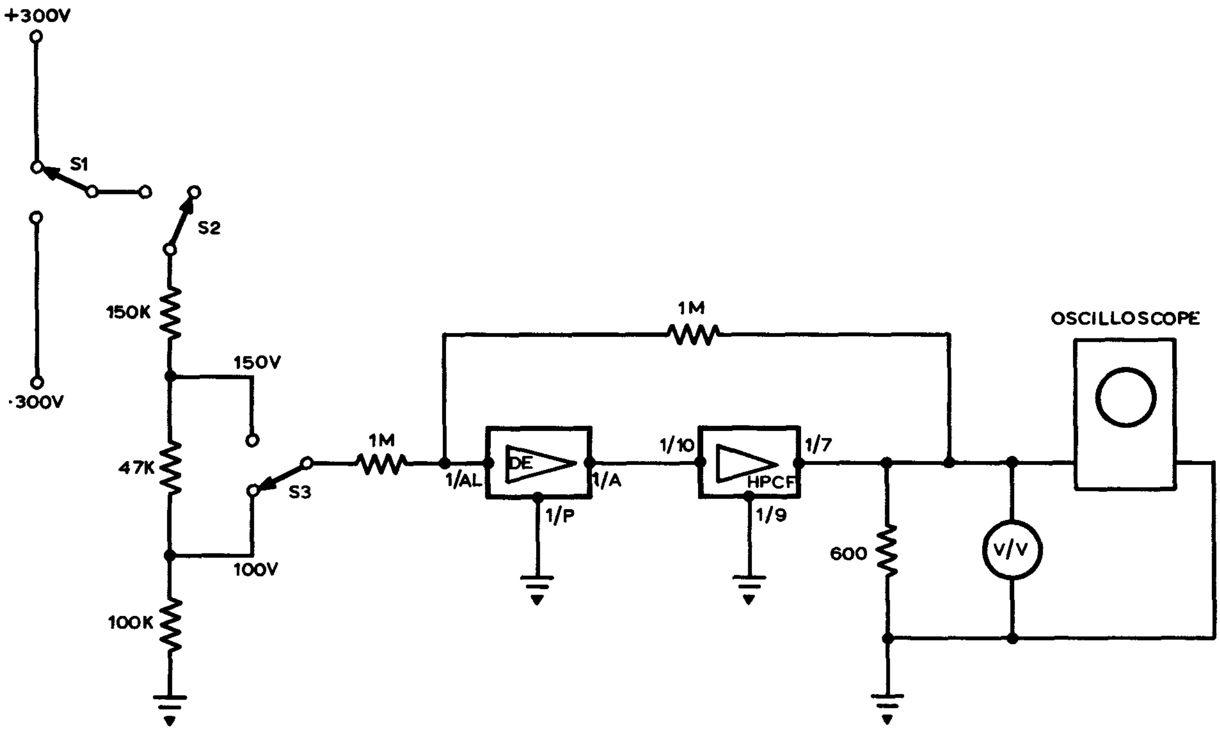


Fig. 2 High-power cathode follower — test circuit

Chapter 3

LIFT LOOP

List of Contents

List of Illustrations

Introduction

1. The lift loop is concerned with the computation of forces along the No.3 wind axis; these forces consist of the positive (upward) force (lift) and the negative (downward) force (aircraft weight). Any unbalance between these two basic forces

results in an acceleration along No. 3 wind axis until the balance of forces is restored by a change of the angle of incidence or of forward speed.

2. In the simulator, the total lift L is computed by summing the normal lift L_N (due to the wings) with the lift due to the tailplane angle of trim and angle of elevator deflection; the effects of gusts and icing are added as required. The total lift is divided by the mass of the aircraft to produce the term $\frac{F_3}{M_T}$ which represents the acceleration along the No. 3 wing axis. This signal is summed with the component of gravitational acceleration ($f(n_1)$) to produce, after correction for bank angle (β) and Mach number (M), the angular velocity signal (ω_2). Under groundborne conditions an oleo leg compression signal (d_m) is added to provide simulation of the touchdown effect and form one of the ground dynamics loops. By summing the ω_2 signal with the pitch rate signal ($\dot{\alpha} - \omega_2$) the incidence angle (α) is produced as a signal and a servo-shaft position.

3. The computation of the lift forces includes the effects of aircraft stall which is defined as the point at which the normal relationship of $\frac{dC_L}{d\alpha}$ departs from the near-linear curve and C_L decreases in value as α is increased. In practice this means that, during straight and level flight, forward speed decrease can be compensated by increased lift only to the point of stall after which the aircraft cannot be maintained in level flight. In the aircraft, and in the flight simulator, pre-stall warning is given by control column shaker devices which are actuated by the pre-stall warning system. Pre-stall warning and aircraft stall are established in two separate discriminating circuits that operate the pre-stall warning stick shaker devices, and establish the point of stall, respectively. The aircraft stall is manifested by an excessive nose-up attitude accompanied by a rapid loss of altitude. The rate of descent is in excess of 6000 ft/m, but because of the large $+\alpha$ angle, the attitude indicators display a normal aircraft attitude.

4. The pre-stall warning system also ensures that the engines are automatically re-ignited, if the flight conditions result in the operation of the pre-stall warning system at an altitude in excess of 25 000 feet. This automatic ignition system thus prevents flame-out of the engines when these are fed with air of low density at a relatively small airspeed.

5. The circuit of the lift loop system also produces a buffet lift signal which provides an irregular drive to the motion drive system for simulation of aircraft stall and high-speed buffet.

LIFT LOOP CIRCUIT

6. The lift loop circuits are concerned with the computation of the following signals:

(1) Gross lift (L)
(2) Acceleration along No. 3 wind axis ($\frac{F_3}{M_T}$)
(3) Stall lift (L_S)
(4) Buffet lift (L_B)
(5) Pre-stall warning
(6) Stall condition
(7) Angular velocity (ω_2)
(8) Angle of incidence (α)
(9) Lift force along No. 3 wind axis ($q\alpha$).

The lift loop signals are generated in circuits which solve the appropriate design equations. The respective component signals are fixed biases or switched voltages which are scaled to represent the terms of the equations. The schematic diagram of the lift loop circuit (Fig. 1) shows the basic lift loops and the routeing of the important signals.

7. The circuit of the lift loop (/212) includes four f(Δ) potentiometers (13AS/a/RV2d, /RV3a, /RV1c and /RV3b) which are actuated by the Δ servo of the wing flaps system (Part 10, Chap. 5). The Δ signals, supplied by these q-signal-fed potentiometers, provide the necessary standard flap functions for the computing circuits of the flight simulator.

Gross lift (/212)

8. Summing amplifier 13CG produces at its output the gross lift signal (L) which contains the lift components corresponding to the terms of the equation:

$$L = 2414{\cdot}1\ q\alpha + 27{\cdot}1\ q + 244{\cdot}1\ f_{1c}(\Delta)\ q - 54{\cdot}3\ f_{3a}(\Delta)\ q + \left[\frac{M_2}{22}\right] \eta$$

$$+ \text{GUSTS} + \text{ICING}$$

The first four terms of the equation represent normal lift which is developed by the aircraft wings. The Mach number effect on the normal lift is negligible and is ignored. The M_2 term includes the lift contribution due to the elevator deflection angle η. The effects of air gusts and icing are switched on by the instructor, as required.

9. The following component lift signals represent the terms of the L equation:

(1) Lift variation due to the incidence angle α and dynamic pressure q; this variable signal consists of two component signals (first and second term) which are supplied via interconnection (9) from the α signal-generating circuit (para.37) and, via interconnection (10), from the drag loop (Chap.2), respectively.
(2) Lift variation due to the flap deflection angle Δ at dynamic pressure q; this signal consists of the sum of two functions of Δ to achieve the required relationship. The $f_{1c}(\Delta)$ q signal, corresponding to the third term of the equation, is obtained from the wiper of Δ potentiometer 13AS/a/RV1c which is fed with the -q signal from the drag loop. The $f_{3a}(\Delta)$ q signal, corresponding to the fourth term, is supplied by Δ potentiometer 13AS/a/RV3a which is energized by the +q signal.
(3) Tailplane contribution to the total (gross) lift; this term includes the effect of the tailplane moment arm M_2 and the elevator deflection angle η. The corresponding signal is fed, via interconnection (14), from the control loading system (Part 9, Chap.1).
(4) Gusts signals which affect the computed value of the gross lift; the corresponding signal is fed via two interconnections, (26) and (27) respectively, from the two gust systems in the rough air system (Part 9, Chap.5) to achieve completely random gust effects.
(5) Lift reduction due to ice formation on the wings. Provided that the de-icing system is not selected, the flight instructor can introduce icing conditions by the use of the ICE switch (de-icing system Part 10, Chap.8); the "icing" signal is then fed from the drag loop (Chap.2) via interconnection (28). The "icing" signal progressively builds-up in amplitude, or decays when the de-icing system is selected.

10. The sum of the gross lift forces is applied to amplifier 13CG to produce, at its output,the +L signal which is applied to the following circuits:

(1) Drag loop, via interconnection (4) as a suitable signal for the undercarriage drag simulation.
(2) Inverting amplifier 13CF/a which produces the -L signal, required by the systems specified on drawing /212, and supplied via interconnection (2).
(3) Stall discriminating circuit of amplifier 13EA/a (para.14) which accepts the +L signal and the $-L_S$ signal via resistors 13C/T5/R26 and /R32, respectively.
(4) The W potentiometer XF/AM/RV2a which is set by the instructor to the estimated aircraft weight; the W potentiometer provides factoring of the +L term, and the product $\frac{L}{M_T}\left[=\frac{F_3}{M_T}\right]$ represents the resulting acceleration along No.3 wind axis. The corresponding signal is supplied, via interconnection (1),to the ω_2 summing amplifier 13AE/b (para.32).

11. The positive output of the +L amplifier 13CG is limited in amplitude to the negative level of the stall lift generating circuit of amplifier 13CF/b (para.16) by diode 13C/T5/MR21. This diode being connected between the input of 13CG and a potential-divider of /R26 and /R32

is, under normal flying conditions, i.e., at speeds above stall speed, non-conducting; at the point of stall (para.14), the +L signal tends to be greater than the $-L_S$ signal and the conducting diode connects /R26 in the negative feedback loop across 13CG.

Stall lift (/212)

12. The stall lift signal (L_S) is computed independently according to the equation:

$$L_S = 810\,q + 281\,f_{2d}(\Delta)\,q - 57\,f_{3a}(\Delta)\,q - 100\,f_2(C.G.)\,q$$

The signals corresponding to the terms of the equation are summed and applied to amplifier 13CF/b which produces a $-L_S$ signal at its output. The $-L_S$ signal feeds the stall lift discriminating circuit of amplifier 13EA/a via resistor 13C/T6/R32. The $-L_S$ signal, algebraically summed with the +L signal at the junction of /R32 and /R26, also provides a limit reference for the +L signal which must not exceed the $-L_S$ signal (para.11).

13. The following signals are summed at the input of amplifier 13CF/b:

(1) The 810 q signal (first term of the equation) is obtained by scaling the +q signal which is supplied from the drag loop via interconnection (5).
(2) The signal corresponding to the second term of the equation is obtained, via interconnections (6) and (16), from the wiper of -q-fed Δ potentiometer 13AS/a/RV2d.
(3) The signal corresponding to the third term of the equation is similarly supplied by the wiper of +q-fed Δ potentiometer 13AS/a/RV3b via interconnections (7) and (32).
(4) The signal corresponding to the fourth term of the equation is supplied from the wiper of the instructor's C.G. potentiometer XF/AM/RV1b which is fed with the -q signal from the drag loop.

Note...
Provision is made for a fifth possible input to amplifier 13CF/b via "master" resistor 13C/T6/R56 which is not normally connected to any voltage source and is used for test purposes only (Chap.1).

Stall lift discriminator (/212)

14. The stall lift signal ($-L_S$) from amplifier 13CF/b and the gross lift signal (+L) from amplifier 13CG are summed at the junction of resistors 13C/T5/R26 and /R32, and the resulting signal is applied to amplifier 13EA/a. The stall conditions are reached when:

$$\text{Stall} = L > L_S$$

15. At the point of stall, the stall discriminator amplifier 13EA/a is fed with a small-value positive signal from the junction of /R26 and /R32, and the negative output of the amplifier energizes the "aircraft stalled" relay coil 13E/T1/RL16 via conducting diode 13E/T2/MR1. Positive operation of the relay is ensured, in this instance, by the increased gain of the amplifier due to the removal of negative feedback (i.e., resistor 13E/T2/R1 earthed via conducting diode /MR1).

16. The input to amplifier 13EA/a is limited in amplitude by the forward resistance of diode 13C/T5/MR21 (para.11) to a small positive voltage; however, a protection circuit of resistors 13E/T2/R5, /R4 and diode /MR2 is included to ensure that the relay-operating voltage, at the output of the amplifier, is kept constant at less than the saturation level of the amplifier for all levels of the positive input signal.

17. At the point of stall, operated contact set 13E/T1/RL16/2 connects +27V supply to the STALL lamp 13BS/LP2 on the state panel on rack 13. Operated contact set /RL16/1 feeds the $+n_1$ signal to the pitch actuator circuits (flight systems, Part 9, Chap.3) to provide the correct pitch attitude display on the flight system instruments. Operated contact set /RL16/3 changes the scaling (by inclusion of /R21) of the $\frac{L}{MT}$ signal, which is used for computation of ω_2 (para.32), to produce the required rate of descent. Operated contact set /RL16/4 feeds the $+n_1$ signal to the drag summing amplifier (Chap.2) to reduce the computed airspeed (V_T), and also to the rear jack circuit of the motion drive system (Part 4, Chap.2) to obtain the correct angle of the motion platform.

Pre-stall warning system

18. The pre-stall warning system provides the pilots with a warning of approaching aircraft stall condition by a shaking action of the control columns. The aircraft warning system contains a pre-stall detector (a vane-operated transducer), control column shaker system and a test switch. In the simulator, the detector vanes are represented by a pre-stall discriminating circuit which actuates the circuits of the control column shakers. The vanes can be affected by ice, and the vane-icing conditions can be simulated; the normal operation of the vanes can also be failed by the instructor.

19. A second function of the stick shaker system is to provide automatic engine ignition, to prevent flame-out, if pre-stall warning should occur at altitudes in excess of 25 000 feet.

20. The pre-stall warning system circuit operates when the gross lift (L) exceeds the "shaker lift" (L_{shaker}), this level of lift being slightly lower in value than the stall lift. To increase the reliability of the system, two independent stick shaker systems (No.1 and No.2) are used. The two systems obtain their d.c. supplies from separate busbars of the aircraft electrical system. Operation of either system actuates the shaker motor

which drives an unbalanced device mounted on the co-pilot's control column; this device sets up vibrations in both control columns.

Stick shaker lift discriminator (/212)

21. The circuit of amplifier 13EA/b represents the pre-stall warning detector and establishes the pre-stall warning lift (L_{shaker}) by comparison of the gross lift signal (-L) with the sum of the relevant component signals; consequently the "stall warning sensor made" relay 13E/T1/RL17 operates when the -L signal exceeds the L_{shaker} signal. The pre-stall warning lift is computed according to the following equation:

$$L_{shaker} = +585\ q + 203\ f_{2d}(\Delta)\ q - 41\ f_{3b}(\Delta)\ q - 162{\cdot}8\ f_{19}(Z)\ q$$

22. The following signals, representing the terms of the equations, are summed at the input of amplifier 13EA/b:

(1) The 585 q signal (first term) which is supplied via interconnection (24) from the drag loop.
(2) The $f_{2d}(\Delta)$ q signal (second term) which is obtained from Δ potentiometer 13AS/a/RV2d via interconnections (16) and (21).
(3) The $f_{3b}(\Delta)$ q signal (third term) which is supplied by Δ potentiometer 13AS/a/RV3b via interconnections (32) and (22).
(4) The signal corresponding to the fourth term of the equation; the signal is obtained from the wiper of q potentiometer 13DS/RV16 which is energized, via interconnection (23), with a signal from Z potentiometer 13AS/RV19 included in the stick shaker circuit (para.27).
(5) The -50V "stall vanes deflected" signal which can be switched into the summing network by the flight instructor by the operation of STALL VANES switch, XF/AL/S12a, during the ground testing procedure (para.29).

23. The functions and polarities of the stick shaker lift component signals are such that the output of amplifier 13EA/b becomes positive when:

$$L > L_{shaker}$$

The positive signal at the output of amplifier 13EA/b causes diode 13E/T2/MR3 to conduct; simultaneously feedback resistor /R11 is removed from the amplifier negative feedback loop and earthed via /MR3. The amplifier gain is thus increased to ensure positive operation of relay 13E/T1/RL17. Contact sets of this relay operated in the stick shaker system (para.25).

Stick shaker system (/218)

24. The No.1 stick shaker system obtains its +27V d.c. supply from the simulated essential d.c. busbar via interconnection (4), circuit breaker PQ/20, and ON/OFF STALL WARNING SYS 1 switch, AD/AL. The No.1 system warning lamp, AD/AM, is connected to the simulated main d.c. busbar via interconnection (3) and circuit breaker PQ/22. The earth return for this lamp is taken via normally-made contact set 13E/T1/RL7/1; the lamp, therefore, lights when /RL7 is not operated, thus indicating that the system is not switched on. When switch AD/AL is set to the ON position, the lamp should extinguish; if it does not, a failure in the essential d.c. busbar, or tripped circuit breaker PQ/20 is indicated. The warning lamp is fitted with the press-to-test facility. The No.2 system warning lamp, AD/AN, is supplied with +27V d.c. from the essential d.c. busbar.

25. When pre-stall conditions are sensed by the stick shaker discriminator (para.23), the "stall warning sensor made" relay 13E/T1/RL17 operated. Provided that the system is switched on, and the aircraft is airborne (operated contact set 13G/T3/RL11/3 of the "weight switch made" relay in the landing gear system, Part 10, Chap.3), operated contact set /RL17/2 connects the energizing supply to the coil of the "shaker relay 1" 13E/T1/RL13, via circuit breaker PQ/21. The shaker motor, AT/AF, is energized by operated contact set /RL13/1 and via two parallel-connected resistors, 13CP/R7 and /R8. Under groundborne conditions, the pre-stall warning system is rendered inoperative by released contact set 13G/T3/RL11/3.

26. The aircraft pre-stall detector vanes are susceptible to icing and are, therefore, provided with heaters to ensure their continued operation when icing occurs. The pre-stall vanes heater supply is routed, in system No.1, via circuit breaker PQ/21, which is wired in series with "shaker relay 1" /RL13. When icing conditions are simulated, the "ice present" relay, 13E/T1/RL5 in the speed indicators system (Part 11, Chap.1), is operated; contact set /RL5/3, wired in parallel with circuit breaker PQ/21 is, therefore, operated. Provided that circuit breaker PQ/21 is made, the operation of the "ice present" relay has no effect on the shaker system. Simulated icing conditions can only prevent the operation of the pre-stall warning system if the heater circuit breaker PQ/21 is tripped.

Automatic engine ignition (/218)

27. The signal from Z potentiometer 13AS/RV19 is proportional to the simulated aircraft altitude; when this signal rises to a value equivalent to a height of 25 000 feet relay 13E/T1/RL15 operates. If pre-stall warning occurs, /RL17 is operated, and relay coil /RL9 energizes via contact sets /RL15/2 and /RL17/2 (No.1 system). Similarly, the coil of /RL10 is energized via contact sets /RL15/1 and /RL17/1 (No.2 system). When either relay /RL9 or /RL10 operates, the AUTO IGNITION ON lamp, AS/AQ, lights. Power is supplied to this lamp from the main d.c. busbar via

interconnection (3), circuit breaker PQ/22, the normally-closed test switches AS/AJ and AS/AH, and either (or both) contact sets /RL9/1 or /RL10/2. The AUTO IGNITION ON lamp is of the press-to-test type, power for the press-to-test facility being supplied from the essential d.c. busbar.

28. The $f_{19}(Z)$ signal is also fed, via interconnection (5), to the $f_{16}(q)$ potentiometer in the stick shaker lift discriminator circuit (para.22(4)) to provide the required Z and q functions.

Pre-stall warning test switches (/218 and /212)

29. Four STALL WARNING switches are fitted on the co-pilot's pedestal for tests of the pre-stall warning system; these switches are:

(1) Test A SYS 1 - AS/AL
(2) Test A SYS 2 - AS/AK
(3) Test B SYS 1 - AS/AJ
(4) Test B SYS 2 - AS/AH.

Before ground tests can be performed on the aircraft pre-stall warning system, it is necessary to deflect the stall vanes (para.18). In the simulator, a STALL VANES switch is provided on the instructor's panel XF/AL (/212). When this switch is pressed, the "stall warning sensor made" relay 13E/T1/RL17 is operated (para.23). Provided that all supplies to the system are present, and that the system ON/OFF switches are ON (/218), the operation of the "test A SYS 1" switch, AS/AL, by-passes the "weight switch made" relay contact set 13G/T3/RL11/3 (released when ground-borne) and the shaker motor runs; the "test A SYS 2" switch operates the shaker motor via No.2 system in a similar manner.

30. Operation of either "test B SYS 1" or "test B SYS 2" switch also causes the shaker motor to run. The first section of "test B SYS 1" switch, AS/AJ, supplies the energizing voltage to the "auto ignitor 1 on" relay 13E/T1/RL9, and operated contact set /RL9/2 energizes the "shaker relay 1" /RL13. Similarly, when the "test B SYS 2" switch, AS/AH, is pressed, the coil of "shaker relay 2" /RL14 is energized via operated contact set /RL10/1. When either switch AS/AJ or /AH (second sections) is operated, the circuit of the AUTO IGNITION ON lamp, AS/AQ, is disconnected from the main d.c. busbar and is fed from the circuit of the engine starting system (Part 7, Chap.3) if "air start" is selected.

31. The "stall warning selected" relay 13E/T1/RL12 is operated, via the third section of switch AS/AJ or /AH, when either of the B test switches is pressed. Contact set /RL12/1 is used in the engine starting system (Part 7, Chap.3) to prevent accidental engine starting while the B test switches are operated.

Angular velocity ω_2 (/203)

32. The circuit of summing amplifier 13AE/b computes the angular velocity about No.1 wind axis (ω_2); this signal is used to derive the direction cosine n_1, the angle of incidence α and the $q\alpha$ signal. The ω_2 signal is obtained by solving the equation:

$$-\omega_2 = \frac{\frac{L}{M_T} - g\left[1 - 0{\cdot}491\left\{f(n_1) + f(\beta)\right\}\right]}{1000\ f_3(M)}$$

The final $-\omega_2$ signal includes a function of the main landing gear damping force (or oleo-leg expansion signal d_m) which is summed with the terms of the equation (when the aircraft is groundborne).

33. The following component signals are summed at the input of amplifier 13AE/b:

(1) The $\frac{L}{M_L}$ signal which represents the acceleration along the No.3 wind axis. This signal is obtained from W potentiometer XF/AM/RV2a in the gross lift circuit (para.10(4)), via interconnection (2).
(2) The $-g$ term is constant and is represented by a fixed bias voltage scaled by resistor 13A/T6/R5.
(3) The component functions of the $-g\left[-0{\cdot}491\left\{f(n_1) + f(\beta)\right\}\right]$ term are computed separately in the direction cosine system (Chap.6) from which the $f(n_1)$ and $f(\beta)$ signals are supplied via interconnections (3) and (4), respectively. Scaling of the two functions is made by two separate resistors (13A/T6/R4 and /R5).
(4) The landing gear oleo-leg expansion signal (d_m) which is supplied from the height and touchdown system (Chap.7), via interconnection (12), when the main wheels are on the ground. The d_m signal is partially damped, via diode 13A/T6/MR2, to the value of directional cosine $-n_1$, to represent the maximum expansion of the oleo leg during take-off as the aircraft is leaving the ground. The $-n_1$ signal is supplied, when groundborne (operated contact set 13A/T1/RL7/4), from the direction cosine system.

34. The sum of the component signals is amplified by amplifier 13AE/b the gain of which is set by M potentiometer 13CS/RV3 to obtain the required division by $f_3(M)$. Thus, the amplifier output consists of the $+\omega_2$ signal which is fed to the α computing circuits of amplifier 13AF (para.36) and, via interconnection (13), to the direction cosine system. The signal at the wiper of the M potentiometer 13CS/RV3 consists of the product of $f_3(M)\ \omega_2$; this signal, available at interconnection (17), is required by the pitch loop (Chap.4).

Angle of incidence α and $q\alpha$ (/203)

35. The angle of incidence α is resolved by integration of the angular velocity

signal (ω_2) with the pitch rate signal ($\dot{\alpha} - \omega_2$) according to the equation:

$$\alpha^o = \int_0^t \left\{(\dot{\alpha} - \omega_2) + \omega_2\right\} dt$$

36. The ($\dot{\alpha} - \omega_2$) signal, from the pitch loop (Chap.4), is summed with the $+\omega_2$ signal, from amplifier 13AE/b (para.34), and the resulting signal is applied, via released contact set 13A/T1/RL12/2 of the "freeze" relay, to the integrating amplifier 13AF. The output of 13AF is limited in amplitude by feedback networks of diodes 13A/T6/MR3 and /MR4 and constitutes the $-\alpha$ signal, the value of which can be "frozen" when the instructor operates the FREEZE switch XF/AM/S5 (Chap.1). When operated, the switch supplies the energizing current to parallel-connected relays 13A/T1/RL1 and /RL12, and to the FREEZE lamp 13BS/LP1 on the state panel.

37. The computed $-\alpha$ signal is fed, via interconnection (10) to the flight computer circuits, to the α servo drive amplifier 13AG/a (para.39), and to q potentiometer 13DS/RV2. The product $q\alpha$, obtained at the wiper of this potentiometer, represents the lift force signal which is supplied to the gross lift summing amplifier 13CG (para.9(1)) and to the pitch system of the control loading system (Part 9, Chap.1).

Angle of incidence servo (/203)

38. The α servo circuit registers the computed α value as a position of a servo shaft which drives the wipers of α potentiometers. The range of registered α values covers the normal useful range of incidence angles from -6^o to $+22^o$.

39. The α servo drive amplifier 13AG/a is fed with the sum of α signals, from amplifier 13AF (para.36 and 37), and α positional feedback signal from potentiometer 13AS/d/RV1a. The speed and direction of rotation of servo motor 13AS/d/M is determined by the amplitude and polarity of the input signal. The gain of the servo drive-amplifier is set by potentiometer 13AS/d/RV501 which is in the negative feedback loop across the drive-stages (13AG/a and power amplifier).

Buffet lift (/205)

40. The buffet lift (L_B) circuit produces a drive signal for the buffet oscillator in the motion drive system (Part 4, Chap.2). The positive L_B signal is passively summed with the negative L (gross lift) signal and only the negative output provides the drive for the buffet oscillator; irregular gust effects are thus obtained in the motion drive system. The amplitude of the drive signal is approximately proportional to:

$$\text{Drive signal} \doteq L_B - L$$

The drive signal is computed according to the equation:

$$L_B - L = 607\ q + 415\ f_{1c}(\Delta)\ q - 60{\cdot}6\ f_{3a}(\Delta)\ q - 2{\cdot}306\ q^2 \cdot f_{16}(Z) - L$$

41. The following signals are summed in the buffet lift circuit:

(1) The gross lift signal (-L) which is supplied by amplifier 13CF/a via interconnection (8).
(2) The signal corresponding to the first term of the equation (607 q); this signal consists of the +q signal, supplied from the drag loop (Chap. 2) via interconnection (1), and scaled by resistor 13E/T5/R42.
(3) The signal corresponding to the second term of the equation and obtained from the Δ potentiometer 13AS/a/RV2d (para. 7) via interconnection (2).
(4) The signal representing the third term of the equation; this signal is supplied by Δ potentiometer 13AS/a/RV3b (para. 7) via interconnection (3).
(5) The signal corresponding to the fourth term of the equation; this signal is produced by multiplication of the -q signal (from the drag loop) by $f_{16}(Z)$, via potentiometer 13ES/RV16, and by q, via potentiometer 13DS/RV4.

The sum of the (L_B - L) signals is fed to the motion drive system via interconnection (9).

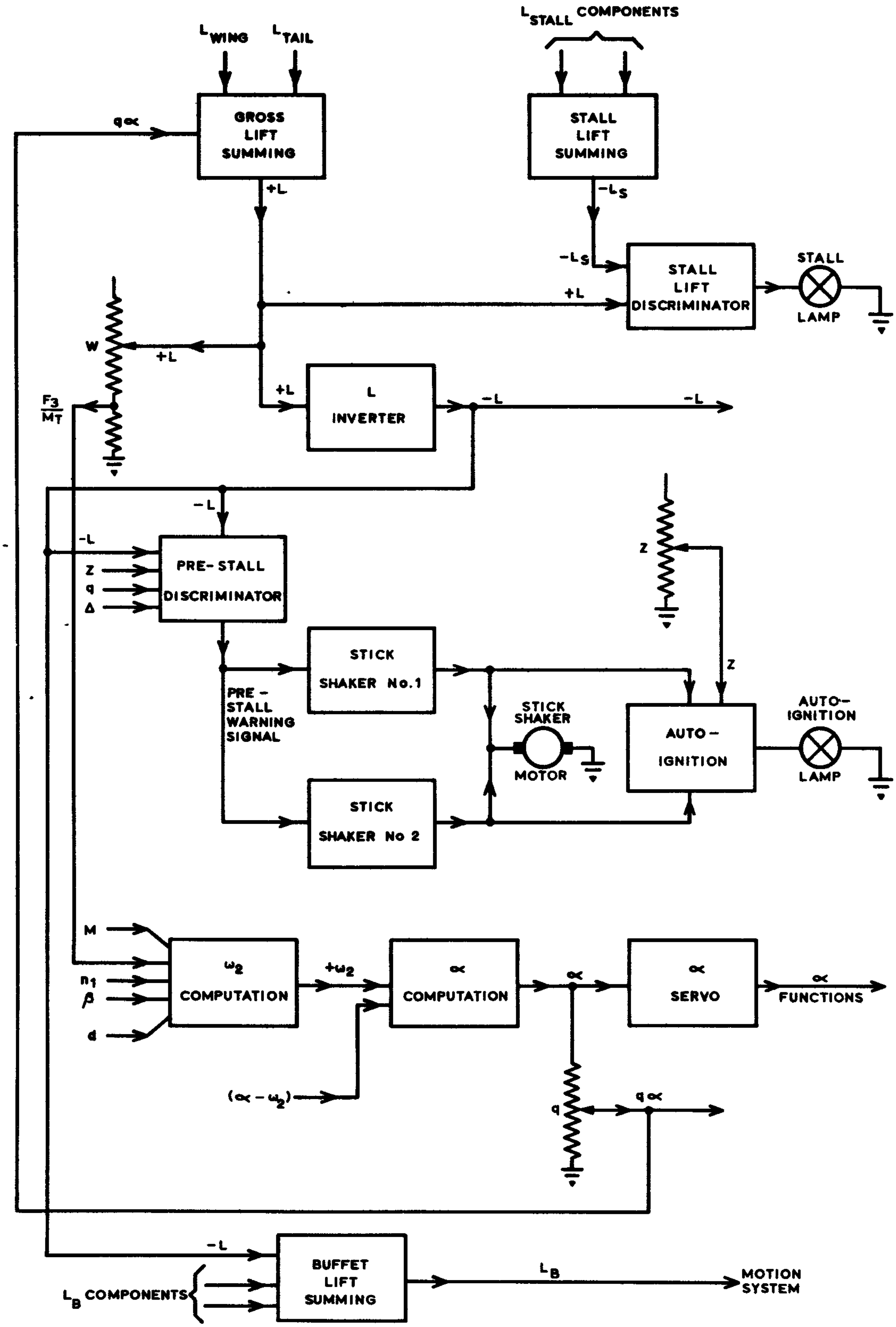


Fig.1 Lift loop system - schematic diagram

Chapter 4

PITCH LOOP

List of Contents

List of Illustrations

Introduction

1. The pitch loop system is concerned with the summing and integration of the pitching moments, and with the computation of the resulting aircraft pitch rate signal ($\dot{\alpha} - \omega_2$); the pitch rate signal is required for the resolution of the angle of incidence α in the lift loop. The centre of origin of the pitching moments is considered to be positioned at 0·33 x $\bar{c}$ (mean wing chord) which is the rearmost permissible position of the centre of gravity (C.G.); alternative positions of the C.G. modify the pitch rate accordingly. The various pitching moments are integrated in a type DEX amplifier, the time constant of which is made proportional to the aircraft moment of inertia about the pitch axis.

2. During flight, the lift forces along No.3 wind axis are balanced in the lift loop; the pitching moments about the No.2 wind axis must also be balanced for equilibrium.

The balance of the pitching moments can be disturbed by changes in the angle of incidence (α), or by changes in forward airspeed, etc.; these variations produce unequal changes in the lift of the mainplanes and of the horizontal tail surfaces. The introduced unbalance in the pitch plane produces a pitch rate until the balance is re-established by a corrective deflection of the elevators, changes in forward airspeed, attitude, etc. Changes in the position of the C.G. also produce pitching moments which must be balanced by the use of the elevator trimming devices, use of elevators, etc. Because of the position of the engines, the thrust force has no appreciable effect on the pitch rate. Extended flaps, speed brake or landing gear, each produce the appropriate contribution to the pitch rate. On the ground, the effect of touchdown, landing gear damping, or the use of the wheel brakes, provide additional pitching moments.

PITCH LOOP CIRCUIT (/214)

3. The circuit of the pitch loop comprises the summing network of the appropriately scaled pitch moment component signals, and the integrating circuit of drift-corrected amplifier 13CB which produces, at its output, the pitch rate signal ($\dot{\alpha} - \omega_2$); the pitch rate signal is supplied, via interconnection (1) to the lift loop (Chap.3). A considerable number of component signals are utilized, and these are described and defined in groups of related signals. The total pitching moment equation, shown on drawing /214, consists of the sum of the individual pitching moment (M_2) equations. The "MASTER" resistor input, via 13C/T3/R43, is not connected, and is used only during setting-up procedure (Chap.1).

Aircraft pitching moments due to lift and C.G. position

4. The origin of the pitching moments is defined as a fixed point located at 0·33 mean wing chord, the length of which is 10·93 feet. The basic pitching moment about the origin of the "clean" aircraft (retracted landing gear, flaps, etc.), with the controls set to the neutral positions, is given by the following equation:

$$M_2 = +254{\cdot}5 \; f_{15}(M)\, q$$

The corresponding signal is obtained from the wiper of M potentiometer 13CS/RV15 which is fed with the +q and -q signals from the drag loop (Chap.2) via interconnections (3) and (4) respectively.

5. The pitching moment due to the variation of gross lift (L) about the origin is computed according to the following equation:

$$M_2 = +0{\cdot}618 \; L$$

The +L signal is obtained from the lift loop (Chap. 3), via interconnection (5).

6. The position of the centre of gravity of the aircraft produces additional pitching moments about the origin (para. 4); the C.G. position is estimated by the fuselage instructor who sets the necessary correction by means of C.G. potentiometer XF/AM/RV1a that is fed with the +L signal; /RV1a wiper supplies a pitching moment signal appropriate to the design equation, which takes into account the preset C.G. shift and the value of gross lift (L), as follows:

$$M_2 = +1 \cdot 75 \ f_{1a}(C.G.)\ L$$

Pitching moments due to flaps

7. During airborne conditions, the extension of wing flaps introduces a pitching moment which can be defined by the following equation:

$$M_2 = +325 \ f_{2d}(\Delta)q - 487 \cdot 5 \ f_{3a}(\Delta)q$$

The resulting pitching moment signal is supplied via two inputs (interconnections (8) and (9)) from the standard flap-functions potentiometers (13AS/a/RV2d and 13AS/a/RV3a, respectively) that are included in the lift loop circuit (Chap. 3).

Pitching moments due to the tailplane and elevators

8. The tailplane and elevator contribution to the pitching moment signal depends on the tailplane lift due to the tailplane trim angle η_T and elevator deflection angle η. The design equation utilizes functions of the respective deflection angles to produce an equivalent signal as follows:

$$M_2 = -195 \ \eta^o_T \ q - 99 \ \eta^o q$$

Signals corresponding to the two terms of the equation are obtained from the wipers of η_T and η potentiometers 14AS/a/RV2a and XF/AQ/RV1a, respectively. Both potentiometers are centre-tapped and are fed with the +q and -q signals to achieve the required polarity of the two signals. The η_T potentiometer 14AS/a/RV2a is driven by the tailplane trim actuator in the trimming systems (Part 9, Chap. 2); the η potentio meter is driven by the elevator jack that is actuated by the Moog valve in the elevator control loading system (flying controls and control loading system, Part 9, Chap. 1).

Airbrake pitching moment

9. The pitching moment due to the extended speed brake is normally proportional to its angle of deflection; the M_2 moment given by the following design equation is

proportional to the full deflection of the speed brake:

$$M_2 = -0{\cdot}43 \times 10^4 \; f_{17}(Z) \; f_{14}(q) \; A.B.$$

The corresponding signal consists of the -A.B. signal which is supplied from inverting amplifier 13FA/b in the airbrakes system (Part 10, Chap.6) and which feeds q potentiometer 13DS/RV14 and cascade-connected Z potentiometer 13ES/RV17 which can be connected, if required, to summing resistor 13C/T3/R33.

Landing gear pitching moments

10. The basic landing gear contribution, during airborne conditions, to the pitching rate is given by the equation:

$$M_2 = +111{\cdot}6\, q$$

The corresponding signal consists of a scaled +q signal supplied by the drag loop via interconnection (7).

11. During groundborne conditions, the compression and expansion of the landing gear oleo-legs is given by the d_m signal (mainwheels) and the d_n signal (nosewheel), respectively.

12. The mainwheel pitching moment is defined as:

$$M_2 = 0{\cdot}171 \times 10^6 \, d_m$$

The $+d_m$ signal supplied from the height and touchdown system (Chap.7) via interconnection (18) provides a progressively-variable signal that represents the nose-down pitching moment as the mainwheel oleo-legs compress, and vice-versa.

13. The nosewheel pitching moment is approximated by the following equation:

$$M_2 = -K\, d_n$$

$$\text{where } K = 65 \times 10^3 \text{ (for compression)}$$

$$= 65 \times 10^5 \text{ (for recoil).}$$

The $-d_n$ signal is also supplied from a common source in the height and touchdown system via interconnections (19) and (20). The polarity of the d_n signal ensures opposite reaction to the d_m signal, and the timing of the signal is such that the nosewheel touchdown and airborne conditions are fully simulated. The pitch rate input $(\dot{\alpha} - \omega_2)$, via diode 13C/T3/MR2, limits the d_n term during recoil of the oleo-legs; this limiting action occurs only when the recoil rate exceeds the maximum expansion rate of the nosewheel leg. Diode /MR1 admits the d_n signal, from interconnection (20), during the recoil condition only.

Pitching moments due to wheel brakes

14. Application of the wheel brakes produces nose-down pitching moments. The port and starboard brake signals, originating in the wheel brakes system (Part 10, Chap.4), are fed to the summing network at the input of amplifier 13CB via interconnections (15) and (16). These signals are available only when the aircraft is groundborne, and when the appropriate contact sets of "wheel brakes available" relays in the wheel brakes system are operated.

Damping in the pitch plane

15. The pitch rate is opposed by the inherent inertia of the aircraft in the pitch plane; this damping is simulated and is proportional to the following equation:

$$\text{Damping} = +0{\cdot}955 \times 10^6 \; f_{11}(Z) \; M \; (\dot{\alpha} - \omega_2)$$
$$+0{\cdot}258 \times 10^6 \; f_{18}(Z) \; [f_3(M) \; \omega_2]$$

The first term of the equation contains the pitch rate signal ($\dot{\alpha} - \omega_2$) which is supplied by amplifier 13CB and which feeds Z potentiometer 13ES/RV11 and the cascade-connected M potentiometer 13CS/RV17. The signals corresponding to the second term consist of the $f_3(M)\ \omega_2$ signal, supplied by the lift loop (Chap.3), and fed, via interconnection (17), to $f_{18}(Z)$ potentiometer 13ES/RV18.

Chapter 5

ROLL, YAW AND SIDEFORCE LOOPS

List of Contents

List of Illustrations

Introduction

1. The roll, yaw and sideforce loops are concerned with the computation of the rotational movements of the aircraft about the No.1 and No.3 wind axes, and the acceleration along the No.2 wind axis. The three computing loops are closely interlinked to represent the inherent movements of the aircraft along or about these axes, e.g., when the aircraft is banked, a yaw movement ensues; when the aircraft is yawed, an angle of bank is introduced.

2. The roll loop computes the aircraft movement about the No.1 wind axis; when the rolling moments are unbalanced, a rate of roll (ω_1) is produced. Because the wind axes are mutually perpendicular at all times, the No .2 and No.3

wind axes are also rolled and assume new positions with new relationship to the flight path which would normally change as a result of the introduced ω_1. A certain amount of damping, proportional to the ω_1 signal and to functions of M and Z, is present in the roll loop to represent the natural restoring moment about the roll axis.

3. The yaw loop is concerned with the computation of the yaw rate $(\dot{\gamma} - \omega_3)$ from the yawing moments due to rudder deflection, asymmetric engine power, differential applications of the brakes, nosewheel steering, etc. Any unbalance of the yawing moments produces a rate of yaw of the aircraft $(\dot{\gamma} - \omega_3)$ with respect to the earth's axes. This rate of yaw is applied directly to the heading system and the respective heading-indicating flight instruments.

4. The function of the sideforce loop is to compute the sideforce which acts along the No.2 wind axis. The major components of this force are due to the rudder deflection which produces a sideforce on the rudder and to the yawing force $(q\gamma)$ caused by the angle of yaw γ which produces an opposing sideforce on the fin. Any unbalance of the sideforce components produces "acceleration along the No.2 wind axis' $(\frac{F_2}{M_T})$.

5. Any yaw of the aircraft results in a "speed component along the No. 2 wind axis" (V_2) which is computed by integration of the "acceleration along the No. 2 wind axis" $(\frac{F_2}{M_T})$ with the appropriately corrected yaw rate $(\dot{\gamma} - \omega_3)$ and the bank angle (β). The computed V_2 speed, appropriately corrected for the effects of height Z and Mach number M, then constitutes the basic yaw force signal $(q\gamma)$ which is fed back to the roll, yaw and sideforce loops to ensure that the close relationship and intercoupling between the loops is accurately maintained. The schematic diagram of the roll, yaw and sideforce loops circuit (Fig. 1) shows the individual basic loops and routeing of the important signals.

ROLL LOOP (/211)

6. The roll loop circuit is concerned with the computation of the angular velocity about the No.1 wind axis (ω_1) according to the equation:

$$\omega_1 = \int_0^t \Big[-0{\cdot}94 \times 10^6 \, f_{16}(M) \, f_{10}(Z) \, \omega_1 + q\gamma \, f_{3d}(\Delta) + 2911 \, q\gamma \, f_{2b}(\alpha)$$

$$- 420 \, \alpha \, \zeta \, q - 0{\cdot}156 \times 10^6 \, (\dot{\gamma} - \omega_3) \, f_{12}(Z) \, f_4(M) \, f_{2c}(\alpha) \, \Delta$$

$$- 5346 \, \phi \, q + K_1 \left\{ 10^7 \, \omega_1 + 0{\cdot}2 \times 10^6 \, \beta^o \right\} \Big] \, dt$$

where $K_1 = 1$ (groundborne), or $= 0$ (airborne).

7. The roll-producing forces, together with the roll-damping forces, are summed at the input of integrating amplifier 13CA which produces at its output the $-\omega_1$ signal representing the angular velocity about the No.1 wind axis. The following signals constitute the rolling moments:

(1) The aerodynamic damping in roll due to ω_1; the corresponding signal is proportional to the first term of the equation and consists of the $-\omega_1$ signal corrected for compressibility and air density by M potentiometer 13CS/RV16 and Z potentiometer 13ES/RV10, respectively.

(2) The rolling moment due to the yaw angle γ at dynamic pressure q; this moment is affected by the incidence angle α, and by the flap deflection angle Δ. The Δ and α corrections are obtained from two shaped potentiometers which provide the signals corresponding to the second and third terms of the equation:

- (a) The $+q\gamma$-fed Δ potentiometer 13AS/a/RV3d (second term)
- (b) The $+q\gamma$-fed α potentiometer 13AS/d/RV2b (third term).

The $+q\gamma$ is obtained from the sideforce loop system (para.20).

(3) The contribution to the rolling moment due to the rudder deflection angle ζ; the effectiveness of rudder deflection is dependent upon the value of q and α. The corresponding signal (fourth term) of the appropriate polarity originates from the wiper of centre-tapped $\pm q$-fed ζ potentiometer XH/AA/RV1b which is actuated directly by the rudder pedals; cascade-connected potentiometer 13AS/d/RV2a provides the α correction.

(4) The rolling moment due to the yaw rate $(\dot{\gamma} - \omega_3)$; this moment affects mainly the spiral motion of the aircraft. The corresponding signal is proportional to the fifth term of the equation. The Z- and M-corrected $(\dot{\gamma} - \omega_3)$ signal is supplied from the yaw loop (para.10(3)) via interconnection (8); the α and Δ correction is provided by potentiometers 13AS/d/RV2c and 13AS/a/RV1d, respectively. Due to the small significance of this moment, only a fraction of the signal is fed to the summing point from potential-divider 13C/T3/R9 and /R10.

(5) The rolling moment due to the aileron deflection angle ϕ; the effectiveness of the ailerons and other control surfaces is proportional to the dynamic pressure q. The corresponding signal (sixth term) originates at the wiper of ϕ potentiometer XF/AP/RV1a which is coupled directly to the control column. This potentiometer is centre-tapped and fed with the +q and -q signals to obtain the correct polarity of the term, depending on the direction of the introduced roll.

(6) The damping of the rolling motion caused by the mainwheels of the landing gear when the aircraft is groundborne. The corresponding signal (seventh term) is proportional to the sum of angular velocity ω_1 and angle of bank β. The $-\omega_1$ signal is supplied by integrating amplifier 13CA; the $-\beta$ signal is supplied from the direction cosine system (Chap.6). Both signals are switched by contact sets (13C/T8/RL1/1 and /RL1/2) of the "mainwheels on ground" relay /RL1 which, together with relay /RL2, is operated by a signal (via interconnection (10)) from the height and touchdown system (Chap.7), when the mainwheels are on the ground.

8. The sum of the rolling moments is integrated by amplifier 13CA, the time constant being established by capacitor 13C/T3/C1 and the respective values of resistors /R2 and /R3. The amplifier output constitutes the $-\omega_1$ signal.

YAW LOOP (/213)

9. Computed in the yaw loop circuit is the yaw rate signal $(\dot{\gamma} - \omega_3)$ which consists of the integrated sum of the relevant yawing moment signals. The total yawing moment is given by the equation:

$$M_3 = 3840\ q\gamma - 815\ q\ \zeta^o - 0{\cdot}192 \times 10^6\ f_{12}(Z)\ M\ (\dot{\gamma} - \omega_3) + 4550\ \omega_1\ f_{19}(M)$$

$$+ [3102\ f_{25}(Z)\ f_{23}(N)\ /\ \text{engine}]\ \text{distance}$$

$$+ \text{BRAKES} + \text{NOSEWHEEL STEERING}$$

where engine distance = 5·57 feet (inner engines)

= 7.85 feet (outer engines).

10. The following individual yawing moments are summed at the input of integrating amplifier 13CC:

(1) Yawing moment due to the angle of yaw γ; the required signal corresponds to the first term of the equation and is supplied from the sideforce loop (para.20) via interconnection (2) as the product $q\gamma$ which is linear to a maximum of 0·25q.

(2) Yawing moment due to the rudder deflection ζ at dynamic pressure q; the $q\zeta$ signal, which corresponds to the second term of the equation, is supplied by rudder-pedal-actuated potentiometer XH/AA/RV1d. This potentiometer is centre-tapped and fed with +q and -q signals from the drag loop (Chap.2) to obtain the correct polarity of the yawing moment.

(3) The damping in yaw, which is proportional to the third term of the equation, and is dependent upon the air density (function of height Z), Mach number (M) and the yaw rate ($\dot{\gamma} - \omega_3$). The corresponding signal (third term) is obtained from yaw-rate-fed Z potentiometer 13ES/RV12 and cascade-connected M potentiometer 13CS/RV4. The product of the three signals is also fed, via interconnection (15), to the roll loop (para.7(4)) and to the sideforce loop (para.17(3)).

(4) Yawing moment due to the angular velocity about the No.1 wind axis (ω_1) which provides the necessary relationship between the roll and yaw loops. The relevant signal corresponds to the fourth term of the equation and is obtained from $-\omega_1$ -fed M potentiometer 13CS/RV19.

(5) Yawing moment due to asymmetric engine thrust which can be either in the forward direction or reversed. The circuits of the four engine thrust systems are similar and take into account the moment arm of the inner and outer engines. The respective yawing moments (fifth term) depend on the thrust developed by the individual engines, the length of the moment arm, polarity of the moment, i.e., port or starboard, and selection of forward or reverse thrust. Signals representing the engine thrust are obtained from the fuel flow system (fuel system, Part 7, Chap.2) via interconnections (7), (8), (12) and (13). The forward or reverse thrust conditions are selected by No.4 contact sets of the "engine in reverse" relays (e.g., 13C/T2/RL3 for No.1 engine); these relays are operated in the engine thrust system (Part 7, Chap.5) when reverse thrust is selected. During forward thrust conditions, the No.4 contact sets are released, thus connecting the port engine thrust signals directly to the summing point at the input of amplifier 13CC, the starboard engine thrust signals being routed via inverting amplifier 13CD/a. When reverse thrust is selected, the No.4 contact sets are operated and the polarity of the thrust signals is reversed, i.e., the port engine thrust signals are routed via inverting amplifier 13CD/a, and starboard engine thrust signals are connected directly to the summing point. Various combinations of reverse and forward thrust are thus possible. The inverting amplifier 13CD/a also receives the starboard brake signal to produce, at its output, the correct polarity signal representing the brake yawing moment (sub-para. (6)).

(6) Yawing moment due to the application of the wheel brakes. The port and starboard brake signals originate in the wheel brakes system (Part 10, Chap.4) and are routed via interconnections (6) (port brake) and (9) (starboard brake). The necessary polarity inversion of the starboard brake signal is made via inverting amplifier 13CD/a (sub-para. (5)).

(7) Yawing moment due to the operation of the nosewheel steering system; the signal from the nosewheel steering system (landing gear system, Part 10, Chap.3), supplied via interconnection (10), is proportional to the nosewheel angle of deflection.

(8) Additional damping in yaw which is due to ground reaction when the aircraft is groundborne. The corresponding signal is proportional to the yaw rate signal ($\dot{\gamma}$ - ω_3) which is applied via operated contact set 13A/T1/RL10/4 when the nosewheel touches down (height and touchdown system, Chap.7). Two different values of scaling of the signal are provided by contact set 13B/T1/RL4/2 which is operated when the aircraft is in motion ($V_T \neq 0$) (drag loop, Chap.2); resistor 13C/T4/R20 then provides the correct scaling of the signal. When the aircraft is stationary ($V_T = 0$), resistor /R20 is short-circuited by released contact set /RL4/2 and the damping is increased.

11. The sum of the yawing moments (M_3) is integrated by amplifier 13CC which produces, at its output, the yaw rate signal ($\dot{\gamma}$ - ω_3). This signal is fed to the turn indicators (Part 11, Chap.5), to the servo of the heading system (Chap.8), and also provides the necessary yaw damping signals.

SIDEFORCE LOOP

12. The function of the sideforce loop circuit is to compute the signals representing the "acceleration along No.2 wind axis" ($\frac{F_2}{M_T}$), the "speed component along the No.2 wind axis" (V_2) and the yawing force ($q\gamma$).

Acceleration along No.2 wind axis (/215)

13. Amplifier 13CD/b is fed with the sum of the sideforce component signals which are represented by the terms of the equation:

$$F_2 = -364\, q\, \gamma + 114\ f_{1c}(\zeta) + \text{GUSTS}$$

14. The following component forces constitute the sideforce F_2:

(1) Sideforce due to yaw angle γ. The corresponding $q\,\gamma$ signal is proportional to the first term of the equation and is obtained from the yawing force circuit (para.20), via interconnection (2).

(2) Sideforce due to rudder deflection angle ζ; the corresponding signal (second term) is supplied by potentiometer XH/AA/RV1c which is directly coupled to the rudder pedals. This potentiometer is centre-tapped and fed with +q and -q signals to obtain the correct polarity of the wiper signal.

(3) Sideforce variation due to the simulated gusts condition; the gusts signal, originating in the rough air system (Part 9, Chap.4), is applied to the summing network via interconnection (3).

15. The sum of the sideforce signals is inverted by amplifier 13CD/b and is factored by the W signal from the feedback W potentiometer XF/AM/RV2c which is set by the instructor to the estimated aircraft weight. The resulting acceleration ($\frac{F_2}{M_T}$) signal is supplied to the yawing force (para.17(1)) and to the slip indicator (Part 11, Chap.5) circuits.

Yawing force (/203)

16. The sideforce loop computes the yawing force $q\gamma$ from the "speed component along No.2 wind axis" (V_2) which is obtained by integration of the component signals according to the equation:

$$V_2 = \int_0^t \left[\frac{F_2}{M_T} - 0.01667\ \beta^{o}\ g + 1000\,M\,(\dot{\gamma} - \omega_3)\ f_{12}(Z) \right] dt$$

17. The V_2 integrating amplifier 13AH is fed with the following signals which correspond to the terms of the equation:

(1) Signal representing the "acceleration along No.2 wind axis" $\frac{F_2}{M_T}$; this signal is obtained from the output of amplifier 13CD/b in the sideforce loop (para.15).

(2) Signal representing the contribution to the yawing force by the angle of bank β; this signal is obtained, via interconnection (7), from the direction cosine system (Chap.6).

(3) Signal corresponding to the third term of the equation; this signal represents the damping in yaw and is, therefore, dependent on the air density (or height Z) and Mach number (M). The signal is computed in the yaw loop (para.10(3)) from which it is supplied via interconnection (8).

18. The sum of the component signal is fed via contact set 13A/T1/RL12/3 (of the "freeze" relay) to the input of amplifier 13AH. The "freeze" relay /RL12 and the parallel-connected relay 13B/T1/RL1 are operated, when the instructor wishes to immobilize the simulator, by the use of the FREEZE switch XF/AM/S5 (Chap.1). The output of amplifier 13AH constitutes the $-V_2$ signal which is used in the computation of the $q\gamma$ signal (para.19) and provides a drive to the rudder control loading system (flying controls and control loading system, Part 9, Chap.1), via interconnection (14). When the aircraft is groundborne, an additional negative feedback loop (resistor 13A/T7/R5) is connected, by operated contact set 13A/T1/RL4/4, across amplifier 13AH to simulate a reduced response to the yawing forces.

19. The yawing force signal $q\gamma$ is computed according to the equation:

$$q\gamma = 1 \cdot 372 \; f_4(Z) \; M \; V_2$$

20. The $q\gamma$ product contains the $-V_2$ output signal of amplifier 13AH (para.17), Mach number M obtained from V_2-fed potentiometer 13CS/RV10, and a function of height Z from potentiometer 13ES/RV4. The resulting $-q\gamma$ signal is fed, via interconnection (18), to the rudder control loading system, and directly to inverting amplifier 13AG/b which supplies the $+q\gamma$ signal to the yaw loop (para.10(1)), to the sideforce computing loop (para.14(2)) and to the roll loop (para.7(2)).

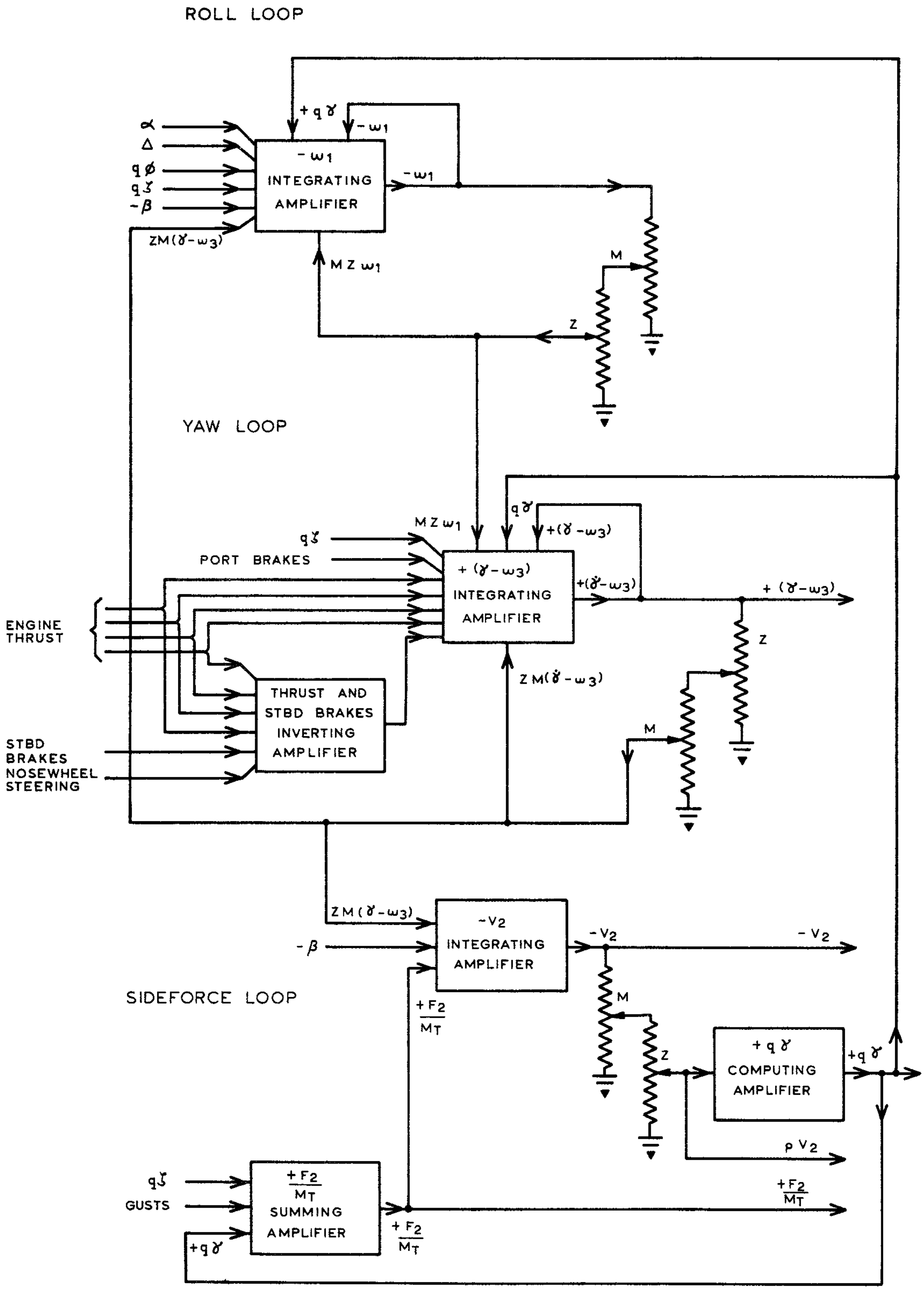


Fig 1 Roll, yaw and sideforce loops — schematic diagram

Chapter 6

DIRECTION COSINE SYSTEM

List of Contents

List of Illustrations

Introduction

1. The function of the direction cosine system is to resolve the angular velocities about the wind axes (ω) into direction cosines and/or into the corresponding attitude angles of the aircraft. In the simulator, the functions of the three direction cosines are fulfilled by two basic signals which are related to the angle of bank β and to the sine of the pitch angle θ. These two signals are shaped to provide the necessary inputs ($f(\beta)$ and $f(n_1)$) for the computation of the ω_2 and α signals in the lift loop.

2. The following signals are computed in this system:

(1) The n_1 signal which is the sine of the angle between the flight path and the horizontal plane (i.e., the sine of the pitch angle θ)
(2) The $f(n_1)$ signal which is an inverted and shaped function of n_1
(3) The angle of bank β which is computed by integration of angular velocity about No.1 wind axis (ω_1)
(4) The $f(\beta)$ signal, which is a suitably shaped function of the angle of bank (β)

ANGLE OF BANK COMPUTATION (/202)

3. The signal corresponding to angle of bank β (in degrees) is computed according to the following equation:

$$\beta^{o} = \int_{o}^{t} \omega_1 \, dt$$

The β integrating amplifier 13BH/b is fed with the $-\omega_1$ signal, computed in the roll, yaw and sideforce loops system (Chap. 5), via released contact set 13B/T1/RL1/2 of the "freeze" relay (Chap. 1).

4. The computed angle of bank β signal, produced at the output of amplifier 13BH/b, is fed, via interconnection (7), to the motion drive system (Part 4, Chap. 2), to the angle of bank actuator of the flight systems (Part 9, Chap. 3) and to the f(β) computing circuits of amplifiers 13BJ/a and 13BJ/b. Amplifier 13BJ/a inverts the β signal which is fed, at the same scale, as $-\beta$, to the motion drive system (Part 4, Chap. 2), to the lift loop system (Chap. 3) and to the shaping network of diode function generators at the input of amplifier 13BJ/b.

5. The shaping network consists of diodes 13B/T6/MR2 to /MR5, scaling resistors /R22 to /R26, inclusive, and resistors /R27 to /R30, inclusive. The function of the diode network is to shape the $-\beta$ signal into an exponential function, f(β), tabulated on drawing /202, and applied to amplifier 13BJ/b.

6. The circuit of amplifier 13BJ/b includes diode 13B/T6/MR1 in the amplifier negative feedback loop to ensure that the f(β) output can be of positive polarity only. This output is applied to the lift loop (Chap. 3) via interconnection (5) and to the n_1 computing circuits (para. 7).

COMPUTATION OF n_1 AND f(n_1) (/202)

7. The n_1 signal is computed according to the following equation:

$$n_1 = \int_{o}^{t} \left[-\omega_2 - \frac{1 \cdot 078 \, g \, f(\beta)}{111 \cdot 7 \, f_5(M)} \, 1 \cdot 153 \, f_{14}(Z) \right] dt$$

Summation of the signal inputs, corresponding to the terms of the equation, is effected at the input of integrating amplifier 13BG. The $-\omega_2$ signal is supplied, via interconnection (2), from the lift loop (Chap. 3), and the function of angle of bank, f(β), signal is supplied by amplifier 13BJ/b (para. 6) for multiplication by (M) and (Z) via potentiometers 13CS/RV5 and 13ES/RV14, respectively. The signal input to amplifier 13BG can be disconnected by contact set 13G/T1/RL1/3 of the "freeze" relay (para. 3). The computed $+n_1$ signal is applied to the height and touchdown system (Chap. 7), to the pitch actuator of the flight systems (Part 9, Chap. 3), and to the n_1 inverting amplifier 13BH/a.

8. The output of amplifier 13BH/a consists of the $-n_1$ signal which is fed, via interconnection (1), to the motion drive system (Part 4, Chap.1), drag loop (Chap.2), lift loop (Chap.3), pitch actuator of the flight systems (Part 9, Chap.3), and to the $f(n_1)$ computing circuit of amplifier 13BF/b via a diode function-generator shaping circuit.

9. The shaping circuit consists of a bias supply, fed from the +50V line via resistor 13B/T5/R24, diodes /MR1 and /MR2 and scaling resistors /R22 and /R23. The function of the diode network is to shape the $-n_1$ signal into an approximately exponential function $f(n_1)$ (tabulated on drawing /202 against the values of n_1). The shaped signal is applied to amplifier 13BF/b.

10. The circuit of amplifier 13BF/b includes diode /MR3 in its negative feedback circuit to ensure that the $f(n_1)$ output can be of positive polarity only. A second negative feedback loop, via resistors /R21 and /R25, establishes the amplifier gain for output signals of less than +50V. When the output exceeds +50V amplitude, diode /MR4 conducts and connects /R26 and /R25 as a potential-divider between the amplifier output and the +50V line. Resistor /R21 then feeds back a portion (approximately two-thirds) of the output signal, and, consequently, the amplifier gain is proportionally increased.

11. The $f(n_1)$ output of amplifier 13BF/b is fed, via interconnection (3), to the lift loop (Chap.3) for the computation of the ω_2 signal.

Chapter 7

HEIGHT AND TOUCHDOWN SYSTEM

List of Contents

List of Illustrations

Introduction

1. The height and touchdown system is concerned with the computation of aircraft height, and with the definition of the points of take-off and touchdown; the system also initiates the necessary actions occurring at the instant of take-off, or touchdown, when definite changes are experienced in the computing loops of the flight computer.

2. The aircraft height system includes a positional servo that provides a mechanical shaft position of the aircraft above airfield pressure height (Z_P). The shaft drives a number of Z potentiometers that are used in the various loops of the flight- and engine-computers to factor the aerodynamic and other related signals as required.

SYSTEM DESCRIPTION (/200)

3. The height and touchdown system comprises the following basic circuits:

(1) The common height-computing circuit which supplies the "height above sea level" integrating circuit and the associated Z servo drive circuit
(2) The "height above airfield" circuit which operates the "initial touchdown" relay
(3) The ground restraints circuit which computes the d_m (main) and d_n (nose) signals representing the landing gear oleo-legs expansion and compression when the aircraft is groundborne, and establishes the point of take-off
(4) A system of "touchdown" relays, the contact sets of which initiate the necessary actions when the aircraft is taking off or landing.

Height-above-sea-level computation

4. The basic height signals are computed by integration, with respect to time, of the n_1 signal supplied from the direction cosine system (Chap.6). The n_1 signal, in itself an integral of the angular velocity signal ω_2, represents the sine of the angle between the flight path and the horizontal plane; thus the height increase or decrease (vertical speed rate) is directly proportional to the n_1 value. The computation of the "height above sea level" signal Z_T takes into account the effect of air density and compressibility as follows:

$$Z_T = 1121 \int_0^t n_1 \; f_9(M) \; f_6(Z) \; dt$$

5. The $+n_1$ signal, fed via interconnection (1), energizes Z potentiometer 13ES/RV6 and the cascade-connected M potentiometer 13CS/RV9. The product $n_1 \; f_9(M) \; f_6(Z)$ is supplied, via interconnection (11) to the rate of climb indicator (vertical speed indicators system, Part 11, Chap.3), to the "point of take-off" discriminating circuit of amplifier 13AC/b (para.12) and to the circuit of the Z_T computing amplifier 13AB (para.6).

6. In flight, the $n_1 \; f_9(M) \; f_6(Z)$ signal is applied, via released contact set 13A/T1/RL12/1 of the "freeze" relay and released contact set /RL4/2, to the input of amplifier 13AB. The "freeze" relay /RL12 is included in the roll, yaw and sideforce loops (Chap.5), and is energized when the flight instructor's FREEZE switch (Chap.1) is operated. Relay /RL4 is one of the "touchdown" relays that are energized when the aircraft is groundborne (para.16); when contact set /RL4/2 is operated, the input to amplifier 13AB is supplied by the h ("height above airfield") computing circuit of amplifier 13AD (para.10 and 11). Amplifier 13AB is also fed with positive bias signal, via 13A/T3/R14, during groundborne conditions. This small-voltage bias stabilizes the output of amplifier 13AB during the transition from airborne to groundborne (or vice versa) conditions when contact set /RL4/2 operates. The bias signal is switched on by contact set /T4/RL1/1 (of the "initial touchdown" relay, para.11(3)) which operates a fraction of a second before the operation of contact sets of the "touchdown" relays (/RL4/1 and /RL4/2).

7. The output of amplifier 13AB constitutes the $-Z_T$ signal which is fed directly to inverter-amplifier 13AC/a of the "height above airfield" circuit (para.10), to the engine speed system (Part 7, Chap.4) via interconnection (9), and via resistor 13A/T3/R2 to the summing network of the Z_P amplifier 13AA (para.9).

8. The circuit of amplifier 13AB normally includes integrating capacitor 13A/T2/C11 which can be disconnected from the amplifier loop and connected to earth, via 13A/T3/R13, by released contact set 13A/T1/RL9/1. Relay /RL9 is de-energized during manual resetting of the Z servo shaft and scale when the AUTO/MAN switch 13ES/S1 is set to MAN. In this instance, the No.2 contact set of relay /RL9 disconnects the $-Z_T$ output of amplifier 13AB from the Z servo drive amplifier 13AA. The sum of the following signals is fed to the input of 13AB in order to maintain the Z_T signal in step with the Z servo scale reading during the manual resetting process:

(1) $-Z_T$ signal via 13A/T3/R2
(2) The positional Z signal from potentiometer 13ES/RV31a
(3) δp signal from the PRESSURE potentiometer 22AG/RV2a which is set by the radio aids instructor to the required barometric pressure.

9. During flight, contact set /RL9/2 is operated and the sum of the $-Z_T$ signal, the positional Z signal and the δp signal (para.8 (1), (2) and (3) inclusive), is fed as the Z_P (pressure height) signal to the input of the Z servo drive amplifier 13AA. The Z_P signal is, therefore, equal to:

$$Z_P = Z_T + \delta_P$$

The gain of amplifier 13AA is preset by potentiometer 13AS/RV502 and velocity feedback is set, during tests, by potentiometer 13ES/RV503. The servo drive circuit includes a standard "limits" circuit (Part 6, Chap.1) as a safety measure.

Height-above-airfield computation

10. The negative Z_T signal from amplifier 13AB (para.8) is inverted by amplifier 13AC/a and is summed with the negative airfield-height signal which is proportional to the setting of the radio aids instructor's AIRFIELD HEIGHT potentiometer 22AG/RV1a. The difference of the two signals represents the "height above airfield" signal (h) as given by the following equation:

$$h = Z_T - \text{AIRFIELD HEIGHT}$$

11. The h signal is fed to amplifier 13AD which provides the following three functions:

(1) For negative output signals up to approximately 50V, the gain of the amplifier is such that a "fine" (-h) signal, scaled at 1 foot/volt, is obtained due to the large value of the negative feedback resistor 13A/T4/R1. This signal is routed via /R5 and /MR3 to the junction of diodes /MR1 and /MR2 which, being biased from the -50V line, shape the -h signal and limit its maximum amplitude to -50V. The -h signal is then fed via contact set 13A/T1/RL4/2 (operated when the mainwheels are on the ground, para.16) to amplifier 13AB of the Z servo drive system.

(2) For negative output signals in excess of 50V, a "coarse" (-h) signal is available via diode /MR4 which, being biased from the junction of /R8 and /R9, conducts and connects a relatively low ohmic-value resistor (/R2) in the negative feedback loop. The signal appearing at interconnection (3) is scaled at 238 feet/volt.

(3) When the h output tends to go positive, i.e., aircraft below airfield height, the feedback loop via /R1 is broken by reverse-biased diode /MR3; consequently, the increased amplifier gain ensures positive operation of the "initial touchdown" relay /RL1 via /MR5 and /R10. Contact set of this relay initiates the "touchdown" sequence (para.17).

Ground-restraints circuit

12. The circuit of amplifier 13AC/b is fed with the $-n_1\ f_9(M)\ f_6(Z)$ product (para.5) via scaling resistor 13A/T5/R4; this input signal represents the rate of descent, which is integrated after touchdown and is supplied as the $+d_m$ signal to the lift loop and motion drive systems.

13. The integration of the rate of descent signal begins at touchdown when /R3 and /C2 are disconnected from the amplifier feedback loop by operated contact set 13A/T1/RL4/3; the computed $+d_m$ signal is fed via /T5/MR2, operated contact set 13A/T1/RL7/1 and interconnection (4) to the $-d_n$ computing circuit of amplifier 13AE/a, to the ω_2 and α computing circuits of the lift loop (Chap.3) and to the individual jack-drive circuits of the motion drive system (Part 4, Chap.2).

14. During the subsequent take-off, the rate of climb signal is integrated towards zero which represents the point of take-off. As soon as the output of amplifier 13AC/b tends to become negative, the integrating loop of capacitor /C1 is earthed by conducting diode /MR1 and the coil of the "point of take-off" relay 13A/T1/RL2 becomes energized; operated contact set /RL2/1 removes the energizing supply and disconnects the self-holding circuit to all the parallel-connected "mainwheels touchdown" relays (para.16) of which two contact sets (/RL4/3 and /RL7/1) operate in the circuit of amplifier 13AC/b. Released contact set /RL4/3 connects /R3 and /C2 across the amplifier with /C2 charging to the instantaneous potential difference; /R3, being of relatively low ohmic-value, reduces the amplifier gain which becomes

insufficient to maintain relay /RL2 in the energized state. Released contact set /RL7/1 disconnects the signal summing networks of the lift loop and of the motion drive system from any possible signal passed by diode /MR2 and provides earthing of the "free" end of interconnection (4).

15. The nosewheel term d_n is computed by summing the $+d_m$ signal with a $-\alpha$ signal at the input of amplifier 13AE/a. For small values of α the output of the amplifier consists of the $-d_n$ signal which is fed to the pitch loop (Chap.4) via interconnection (2) provided that contact set /RL10/1 of the "nosewheel touchdown" relay (para.16) is operated. During take-off, the $-\alpha$ signal increases sufficiently to produce a positive signal at the output of amplifier 13AE/a. Diode /MR3 then begins to conduct, thus earthing feedback resistor /R11 and increasing the amplifier gain sufficiently to energize the "nosewheel airborne" relay /RL3. Contact set /RL3/1 controls the circuit of the "nosewheel touchdown" relay /RL10 (para.17 and 18).

Touchdown relays

16. The groundborne and airborne conditions of the simulated aircraft are decided by a number of parallel-connected relays (13A/T1/RL4 to /RL8, inclusive) that represent, when energized, the "mainwheels touchdown" condition; a separate relay (/RL10 represents, when energized, the "nosewheel touchdown" condition. Contact sets of these relays operate in various circuits of the flight computer where a definite switching action is required during the transition from the airborne to the groundborne state and vice versa.

17. During groundborne conditions, the energizing supply for all the touchdown relays is routed via contact set 13A/T4/RL1/1 of the "initial touchdown" relay (para.11(3)) and self-holding contact set /RL4/1. The "mainwheels touchdown" relay-circuit is completed via released contact set /RL2/1 of the "point of take-off" relay (para.14); the "nosewheel touchdown" relay-circuit is controlled by contact set /RL3/1 of the "nosewheel airborne" relay (para.15). At take-off, contact set /RL2/1 is operated and breaks the holding circuit of contact set /RL4/1; consequently, all the "touchdown" relays are de-energized until the next landing.

18. During the final stages of a landing, contact set /RL1/1 is operated when the aircraft height equals the airfield height and the coils of the "mainwheels touchdown" relays are energized; the "nosewheel touchdown" relay (/RL10) is operated when contact set /RL3/1 (of the "nosewheel airborne" relay, para.15) is released.

19. Connected in parallel with the touchdown relays are the NOSEWHEEL TOUCHDOWN lamp 13BS/LP3 and the MAINWHEELS TOUCHDOWN lamp /LP4; these lamps are mounted on the state panel on rack 13 and indicate, when lit, that the nosewheel and mainwheels, respectively, are "on the ground".

20. Due to the considerable number of the required switched functions at "touchdown", additional "touchdown" relays are parallel-connected, via interconnections (10) and (12), in the motion drive system (Part 4, Chap. 2) and in the roll, yaw and sideforce loops (Part 8, Chap. 5), respectively.

Chapter 8

HEADING SYSTEM

List of Contents

List of Illustrations

Introduction

1. The heading system comprises the heading servo and its associated drive amplifier: the system electro-mechanically integrates the yaw rate signal ($\mathring{\gamma} - \omega_3$) and produces the heading angle δ as a servo-shaft position. The servo shaft provides the aircraft heading angle for the chart recorder and radio aids systems; this angle is displayed by the pointer of the heading indicator on the radio aids console.

HEADING SERVO (/337)

2. The yaw rate signal ($\mathring{\gamma} - \omega_3$) derived from the roll, yaw and sideforce loops system (Chap.5) is fed to amplifier 14E/F via scaling resistor 14E/T3/R32. The amplifier output provides the drive for the heading servo motor 22AF/A/X1. To obtain the integrating operation of the servo system, a velocity feedback signal from the servo generator is fed, via scaling resistor 14E/T3/R31, to the servo-drive amplifier input. The rate of rotation of the servo shaft is preset during tests by potentiometer 22AF/A/RV1 for the required response.

3. The servo motor is short-circuited by operated contact set 21A/RL36/1 when the airspeed (V_T) is zero. This arrangement prevents servo-drift during periods of groundborne checks, etc., when the forward speed is zero. The coil of relay /RL36

is included in the circuit of the chart recorder system (Part 12, Chap. 2), and is energized when the $V_T = 0$ condition is detected in the drag loop (Chap. 2).

4. The servo shaft position corresponds to the heading angle δ which is displayed on the heading indicator fitted to the GCA panel 22AF; the servo shaft also drives the heading resolver 22AF/A/RS1 of the chart recorder system (Part 12, Chap. 2), the torque differential transmitters of the RMI system (Part 12, Chap. 9), and the E2B stand-by compass drive transmitter (Part 11, Chap. 4). The compass cards of the flight instruments display magnetic heading, whereas the chart system contains a magnetic variation control which corrects the movement of the pens to achieve true heading (track).

PART 9

FLIGHT SYSTEMS

Chapter 1

FLYING CONTROLS AND CONTROL LOADING SYSTEM

List of Contents

List of Illustrations

Introduction

1. The pilot's and co-pilot's flying controls consist of the conventional control wheels (mounted on the control columns), rudder pedals and trim controls. The flying controls are connected to the appropriate control surfaces of which the ailerons and elevators are, normally, actuated via a hydraulic boost system to reduce the required control-operating forces. The rudder controls are not boosted. The aileron- and rudder-control surfaces are fitted with trim tabs; pitch trim is accomplished by variation of the tailplane angle. The trim surfaces reduce the forces, exerted by the pilot on the controls, and thus

improve the handling qualities of the aircraft. When an autopilot system is fitted, the elevator, aileron, and rudder controls can be operated automatically via servo-motors.

2. Movement of the aircraft about the rolling, yawing, and pitching axes is governed primarily by the angular movement of the ailerons, rudder and elevator, respectively. The effectiveness and stiffness of the controls is dependent on the velocity and density of air flowing over the control surfaces. Any increase in indicated airspeed results in the controls becoming progressively stiffer to move and becoming more effective. For example, at low indicated airspeeds, a large rotational movement of the control wheel, which operates the ailerons, produces a rate of roll equivalent to that obtained by smaller movements at higher airspeeds. Thus the forces which are exerted by the pilot's hands and feet, depend on the angular deflection of the control surfaces, the aircraft attitude, airspeed, and air density.

3. A RUDDER LOCK handle, situated on the upper panel of the cockpit centre stand, is also included in the control loading system; this handle must be operated to lock the rudder in the neutral position when the aircraft is parked.

4. In the simulator, three electro-hydraulic control-loading units (CLU) provide simulation of the various forces opposing the pilots' movements of the flying controls. Each CLU contains a hydraulic jack which provides the respective control surface load and which is linked, via a torsion bar and mechanical linkage, to the flying controls. The jacks are controlled by Dowty Moog valves which govern the direction of flow and flow rate of the hydraulic fluid supplied to the jacks.

5. The loads applied by the pilots on the flying controls (control demand signals) are obtained as electrical signals from torsion bar potentiometers which measure the amount of twist between the control end and the jack end of the torsion bar.

6. Information concerning the position of the controls is derived from precision potentiometers which are driven directly by the controls. Because the deflection angle of the control surfaces is proportional to the deflection of the controls, the signals from these potentiometers represent the elevator, aileron and rudder deflection angles (η, ϕ and ζ respectively) which provide positional signals in the CLU system; functions of these signals are used in the flight computer systems for elevator, aileron and rudder surface effects.

7. Any force applied to a particular flying control is opposed by the hydraulic pressure maintained in the jack. The CLU computing circuits establish the signal voltage which is applied to the Dowty Moog valve solenoid; this voltage consists of the sum of the following signals:

(1) Control load signals, proportional to the deflection of the flying controls, from the torsion bar-driven potentiometers.

(2) Positional signals from the control-driven potentiometers.

(3) Signals from potentiometers which represent the trim tab angular deflection; the wipers of these potentiometers are driven by the respective trim controls (Chap.2).

(4) Signals from the flight computer; these signals correspond to the actual flying conditions and parameters, e.g., dynamic pressure q, aircraft attitude angles, etc.

The sum of the component signals is applied to a d.c. amplifier which drives the Dowty Moog valve and the associated safety circuits.

8. Each CLU system is fitted with safety interlocks and cut-out circuits to prevent structural damage to the simulator as a result of electrical faults, erroneous signals, etc.

9. Hydraulic power for the control loading systems is obtained from the hydraulic power supply system (Part 4, Chap.1) which also provides power for the cockpit motion system.

10. A relay circuit represents the aileron and elevator boost systems. Contact sets of these relays, operated when the appropriate boost system is selected, change the scaling of the input signals to the aileron and elevator CLU computing amplifiers from the torsion bar potentiometers. This change of signal-scaling results in a reduction of the force required to operate the controls when boost is selected.

CONTROL-LOADING SYSTEMS

11. Three independent CLU's are fitted, each unit being mechanically linked to one particular flying control. The basic circuits of the three CLU systems are similar and consist of a d.c. summing amplifier, drive circuits for the Dowty Moog valve, and safety circuits. The major differences between the circuits are in the signal summing networks due to the particular response and characteristics of each control; each summing network is, therefore, described individually. The safety circuits are identical and only one (the aileron CLU system) is described.

Aileron control-loading computation (/220)

12. The summing amplifier of the aileron control-loading system, 13EH/a, is fed with signals corresponding to the control-loading force F, a control deflection demand signal and an a.c. safety input signal. The component signals are as follows:

(1) Loading force F given by the following equation:

$$F = 18{\cdot}8 \ \phi \ f_{11}(q) + 0{\cdot}049 \ \phi_T \ q$$

(a) The first term of the equation is proportional to the aileron deflection angle (ϕ) at dynamic pressure (q) which is supplied from the drag loop system (Part 8, Chap.2). The corresponding signal is supplied from jack-driven potentiometer XF/AP/RV1b which is centre-tapped and fed with +50V and -50V. The output of this potentiometer feeds q potentiometer 13DS/RV11 (for multiplication by $f_{11}(q)$), and the safety circuit (para.24(4)) via interconnection (2). Resistor 13E/T8/R6 provides scaling of the product under normal operating conditions (contact set 13D/T9/RL1/2 released). Relay /T9/RL1 is operated when the aileron CLU system is reset (para.32); when contact set /RL1/2 is operated summing resistor /T2/R22 is included in the scaling network to reduce the signal and, consequently, the operating forces when the system is being reset.

(b) The second term of the equation is proportional to the aileron trim deflection angle (ϕ_T) at dynamic pressure (q); the corresponding signal is obtained from the wiper of $\pm$q-fed potentiometer 14AS/b/RV2b. The signal is scaled by resistor /R7.

(2) The signal corresponding to the rotational force applied to the control wheel and derived from torsion bar potentiometer XF/AP/RV2a. Under normal operating conditions, i.e., with aileron boost in use, the signal is scaled by parallel-connected resistors 13E/T8/R4 and /R5 (connected via operated contact set 13E/T7/RL1/1), and series resistor /R3. Contact set /T7/RL1/1 (para.38) is released when the aileron boost system is switched off, in which instance the manual force required for operation of the aileron wheel must be increased for the same aileron deflection; the scaling of the torsion bar potentiometer signal is, therefore, adjusted by disconnecting /R5.

(3) The a.c. safety input signal supplied from a potential divider, 13E/T8/R9 and /R10, which is fed with 115V, 400c/s. The signal is scaled via resistor /R8 and its function is described in para.22 and 23.

13. The sum of the four input signals is applied to the "demand" amplifier 13EH/a; the amplifier gain is determined by the setting of potentiometer /RV2. The amplifier output is fed to the safety-circuit amplifier 13DF/a (para.24), and to the Dowty Moog valve via resistor 13D/T4/R54, operated contact sets /T2/RL19/2, /RL16/2, (±50V available relays), /RL4/3, /RL5/3, /RL6/3 and /RL7/3 ("±300V reg." and "±300V unreg." available relays); the circuits of the "power-available" relays are included in the safety circuit (para.28 and 31).

<u>Rudder control-loading computation</u> (/221)

14. The summing amplifier 13EH/b of the rudder control-loading system is fed with signals similar to those of the aileron CLU system. These signals include the control-loading force F, a control demand signal from torsion bar potentiometer XH/AA/RV2a and the safety input signal fed to the system via interconnection (11). The rudder control-loading force F is computed according to the following equation:

$$F = -171 \cdot 5 \, f_{13}(q) \, \zeta + 3 \cdot 53 \, (q\gamma) + \tfrac{1}{2}\rho \left[65 \cdot 6 \, f(V_2)\right] + 2 \cdot 34 \, q \, \zeta_T$$

The four terms of this equation are represented as follows:

(1) The first term $-171 \cdot 5 \, f_{13}(q) \, \zeta$ is proportional to the rudder angular deflection, at dynamic pressure q, obtained from potentiometers XH/AA/RV1a and 13DS/RV13.

(2) The second term $3 \cdot 53 \, (q\gamma)$ represents the sideforce which can be obtained from the roll, yaw, and sideforce loops systems (Part 8, Chap.5) via interconnection (15), if required.

(3) The $\tfrac{1}{2}\rho \left[65 \cdot 6 \, f(V_2)\right]$ term includes the correction due to air density ρ which is obtained as a height function from Z potentiometer 13ES/RV22, and a sideways velocity term, fV_2, obtained via interconnection (16), and shaped by Zener diodes /MR16 and /MR17 to produce a signal approximating $V_2 |V_2|$.

(4) $2 \cdot 34 \, q \, \zeta_T$ is proportional to the rudder trim tab angular deflection, at dynamic pressure q, obtained from the ±q-fed potentiometer 14AS/c/RV2a.

15. A "rudder gust lock" circuit simulates the locking of the rudder when the aircraft is parked. The rudder can be locked by operation of the RUDDER LOCK handle on panel CB only when the rudder pedals are centralized. When the rudder is locked, the "rudder lock" microswitch CB/AU and the "rudder central" microswitch XL/AB are operated, and the wiper of potentiometer XH/AA/RV1a, which is at earth potential in its central position, is connected to the input of amplifier 13EH/b via /T8/R23. As this summing resistor is of low ohmic-value, any subsequent positional signals are increased

considerably and the rudder control system is thus effectively immobilized. During normal operation of the rudder control system, resistor /R23 is earthed through the microswitches to prevent any pick-up of a.c. voltages on the relatively long connecting wires.

Elevator control-loading computation (/222)

16. The elevator control-loading system is similar to the aileron and rudder control-loading systems. The elevator control-loading force (F) is given by the following equation:

$$F = 0{\cdot}0685\ f_{12}(q)\ \eta\ -\ 0{\cdot}00855\ (q\,\alpha)\ +\ 0{\cdot}0224\ \eta_T\, q$$
$$-0{\cdot}0043\ q\ +\ 0{\cdot}08\ f_{2d}(\Delta)\ q\ -\ 0{\cdot}0214\ f_{3b}(\Delta)\ q$$

The six terms of this equation are as follows:

(1) The first term, $0{\cdot}0685\ f_{12}(q)\ \eta$, is proportional to the elevator angular deflection at dynamic pressure q; the corresponding signal is obtained from the wiper of q potentiometer 13DS/RV12 fed from the wiper of the positional η potentiometer XF/AQ/RV1b which also supplies the pitch trimming system (trimming systems, Chap. 2) via interconnection (2).

(2) The $-0{\cdot}00855\ (q\,\alpha)$ term represents the angle of incidence at dynamic pressure q; this signal can be obtained from the roll, yaw, and sideforce loop systems (Part 8, Chap. 5) via interconnection (7), if required.

(3) The $0{\cdot}0224\ \eta_T\, q$ term includes the tailplane trim angular deflection at dynamic pressure q; the corresponding signal is obtained from the wiper of q potentiometer 13DS/RV9, which is fed from η_T potentiometer 14AS/a/RV2b.

(4) The $-0{\cdot}0043\ q$ term is proportional to the dynamic pressure q obtained from the drag loop (Part 8, Chap. 2) via interconnection (8).

(5) The effect of extended flaps on the elevator control-loading force is given by two $f(\Delta)$ functions at dynamic pressure q; these are the $0{\cdot}08\ f_{2d}(\Delta)\ q$ (+ve) and the $-0{\cdot}0214\ f_{3b}(\Delta)\ q$ signals which are obtained from the lift loop via interconnections (11) and (12), respectively.

17. The control deflection demand signal from the torsion bar potentiometer XF/AQ/RV2a is fed to summing amplifier 13EJ/a via scaling resistors directly, and, via inverting amplifier 13EJ/b and an attenuating network, as a permanent pre-load signal corresponding to a fixed pre-load of 4 lb which opposes the demand signal. The direct signal is scaled, under normal operating conditions with

elevator boost in use, by resistor 13E/T8/R38 and parallel-connected resistors /R59 and /R60. Contact set /RL2/1 (connected in series with /R60) is released when elevator boost is switched off.

18. The pre-load signal amplifier 13EJ/b obtains its input signal from the junction of /R58 and /R59. The amplifier output is fed to amplifier 13EJ/a via an attenuating network of resistors /R42 and /R44. Diodes /T2/MR30 and /MR31 determine the pre-load signal and also prevent saturation of amplifier 13EJ/b when large input signals are present.

Dowty Moog valve

19. The Dowty Moog valve employs a pilot stage which consists of two opposed nozzles with an interposed flapper. Movement of the flapper, controlled in either direction by an electro-magnetic actuator (solenoid), causes a drop in pressure across restrictors in the supply lines to the nozzles. This change of pressure permits movement of the valve's main piston; the piston then passes hydraulic fluid to one side of the jack and ports the fluid from the other side to the return line.

CLU SAFETY SYSTEMS

20. A comprehensive safety system is incorporated in each of the control-loading systems to protect the Moog valve solenoids and to prevent violent movement of the controls during electrical fault conditions. The basic action of the safety system is to remove the electrical drive from the Moog valve; this is achieved by the inclusion of six series-connected contact sets in the supply line to the Moog valve solenoid. Four of the associated relay coils (13D/T2/RL4, /RL5, /RL6 and /RL7, in the aileron system, /220) are energized (para.31) from the ±300V regulated and unregulated supplies which are used to power the control-loading systems demand amplifiers. Two associated relays (/RL19 and /RL16) are energized when the ±50V supplies are available and the trip circuits are reset (para.28). Additional protection is provided by resistor 13D/T4/R54 and Zener diodes (13D/T4/MR57, /MR58, /MR59 and /MR60) which limit the Moog valve solenoid supply to ±11·2V.

21. The three safety circuits associated with the control-loading systems are identical, except for component references; only the aileron safety system (/220) is described.

Aileron CLU safety system

22. The safety circuit consists of a d.c. amplifier which is fed with a.c. and d.c.

signals. The amplifier output is rectified and, under normal operating conditions, energizes two relays common to the safety circuit and to the CLU reset system.

23. An excessive input to the demand and/or the safety circuit amplifier results in saturation of the respective amplifier; the a.c. component of the signal is, therefore, ineffective, and the two relays are released, thus tripping the system. The 400c/s safety signal is applied to the demand amplifier from a 115V source via a potential divider (para. 12(3)).

Safety circuit (/220)

24. A.C. and d.c. signals from the control-loading circuit are summed and fed to the input of amplifier 13DF/a. These signals are obtained from the following sources

(1) A 400c/s signal from the output of amplifier 13EH/a via resistor-capacitor network /T4/C43, /R47 and /C42.

(2) A signal from the wiper of torsion bar potentiometer XF/AP/RV2a via /R49, and a resistor-capacitor shaping network /C44 and /R48. Capacitor /C44 and resistor /R48 present a low-impedance input to the safety amplifier at rapid movements of the control.

(3) A signal from the wiper of torsion bar potentiometer XF/AP/RV2b via resistor /R50. This potentiometer is centre-tapped and ganged to the "a" section (sub-para. (2)).

(4) A signal from the wiper of positional potentiometer XF/AP/RV1b via capacitor /C45 and summing resistor /R53. Capacitor /C45 presents a low-impedance input to the safety amplifier at rapid movements of the control.

25. Amplifier 13DF/a operates at high gain due to the high value of feedback resistor /R41. The 400c/s signal appearing at the amplifier output is fed, via capacitor /C41, to bridge rectifier /MR51 to /MR54, inclusive.

26. The a.c. return arm of the bridge rectifier is connected, via a stabilizing network consisting of resistors /R42, /R43 via scaling resistors /R44, /R45 and Zener diodes /MR55 and /MR56, to the input of amplifier 13DF/a. This network shapes the feedback signal supplied to the amplifier input via scaling resistors /R44, /R45 to produce a non-linear amplifier output response which is desired for positive operation and release of the "trip circuit reset" relays (para. 27).

27. The coils of "trip circuit reset" relays /T3/RL5 and /T3/RL6 are fed with the rectified bridge output via the AILERON reset switch XH/AB/S3a or operated contact sets /T2/RL19/1 and /RL16/1.

28. When the system is switched on or is tripped, operation of the reset switch XH/AB/S3a, completes an energizing path for relays /T3/RL5 and /RL6; the coil of "trip circuit reset" relay /T2/RL8 is then energized from the +27V general supply, via operated contact sets /T3/RL5/1 and /T3/RL6/1. Operated contact sets /RL8/1 and /RL8/2 energize relays /T2/RL19 and /RL16 from the +50V and -50V supplies, respectively. Operated contact sets /T2/RL19/1 and /RL16/1 by-pass reset switch XH/AB/S3a, and provide a holding circuit for the coils of relays /T3/RL5 and /RL6.

29. Operated contact sets /T2/RL19/2 and /RL16/2, together with contact sets of the "±300V reg. and unreg. available" relays, complete the signal path to the Moog valve solenoid. When any of these contact sets is released, the solenoid is earthed via resistor XF/AP/R3.

CLU safety reset (/223)

30. When the flight simulator h.t. power is switched on, the +27V, ±50V and the ±300V regulated and unregulated supplies become available. The hydraulic flow restrictor solenoid is de-energized, resulting in a restricted flow of hydraulic fluid to the Moog valves, the "reset" relays are released, the "CLU tripped" relays are operated and the "system tripped" warning lamps are lit. The control-loading systems are thus initially in the "tripped" state and must be reset.

31. The "power available" relays, 13D/T2/RL6 (+300V unreg.), /RL7 (-300V unreg.), /RL4 (+300V reg.) and /RL5 (-300V reg.), are energized when the respective supplies are available. Relays /RL6 and /RL7 are energized via voltage-dropping resistors; the "+300V reg." supplies relays /RL4 and /RL5 are energized via a discriminating circuit included in unit 13D/T10 which ensures that the relays are energized if both the h.t. and l.t. supplies are available. Contact sets of these relays operate in the safety circuit of the Moog valve (para.20).

32. The three control-loading system reset circuits are identical, and only the resetting of the aileron control-loading system is described. Operation of the AILERON reset switch XH/AB/S3b energizes the coil of "aileron reset pressed" relay /T9/RL1. Operated contact set /T9/RL1/1 completes the energizing path for the coil of heavy-duty relay MCB/RL11; the restrictor solenoid is then energized by operated contact set MCB/RL11/2, thus providing full hydraulic-fluid flow to the control-loading systems.

33. To maintain full hydraulic pressure the coil of relay MCB/RL11 is held energized via a circuit of series-connected, operated contact sets of the "-50V available and trip circuit reset" relays, i.e., 13D/T2/RL16/3 (aileron system, para.28), /RL15/3 (rudder system) and /RL3/3 (elevator system), and via operated contact set MCB/RL11/1.

34. If one of the CLU systems is tripped (e.g., the aileron CLU system), released contact set of the respective "-50V available and trip circuit reset" relay (13D/T2/RL16/3) then energizes the corresponding "CLU system tripped" relay (13D/T2/RL14). Because the operation of relay/T2/RL14 is delayed by /T2/R14 and /T1/C14, contact set /T2/RL14/1 operates after the release of contact set MCB/RL11/1 and relay MCB/RL11 is de-energized thus restricting the hydraulic pressure (para.32). Operated contact set /T2/RL14/2 completes the circuit of the AILERON tripped warning lamp XH/AB/S3/LP (fitted under the push-button of the AILERON reset switch) and the lamp lights.

35. If subsequent resetting of the aileron CLU is not successful, due to a fault, and the two other CLU systems are required to operate at full hydraulic pressure, resetting either of the two other systems will re-energize relay MCB/RL11. This relay will be then held energized via operated contact sets 13D/T2/RL3/3, /RL15/3, released contact set /RL16/3, operated contact set /RL14/1, diode /MR23 and operated contact set MCB/RL11/1; full flow to the elevator and rudder CLU systems is thus restored.

AILERON AND ELEVATOR BOOST (/223)

36. Normally, the aileron and elevator boost systems are powered by the No.1 and/or the No.2 hydraulic system, the boost hydraulic power being selected by two BOOST HYD PRESS ON/OFF switches on the pilots' control column pedestal. Two switches are provided for each boost system: SYS 1 switch selects the No.1 hydraulic system, and SYS 2 switch selects the No.2 hydraulic system.

37. Operation of the boost systems is dependent on the availability of the No.1 or of the No.2 hydraulic supplies at a pressure in excess of 1500 lb/in^2, and on the availability of the main d.c. busbar electrical supply. The +27V general supplies (available when the No.1 and No.2 hydraulic supplies exceed 1500 lb/in^2), are routed to the BOOST HYD PRESS ON/OFF switches AR/AF, /AD, /AG and /AE, via interconnections (7) and (8), circuit breakers SG/116 and SG/117, (BOOST CONT NO.1 and BOOST CONT NO.2, respectively), contact sets 13E/T1/RL4/3 and /RL4/4 (of the "main d.c. busbar available" relay) and via diodes 13E/T7/MR21 to /MR24 to the "boost on" relays, 13E/T7/RL1 (aileron) and 13E/T7/RL2 (elevator); these relays are operated when the respective boost system is switched on. The OR-connected diodes /MR22 and /MR24 feed the supply from the SYS 1 or SYS 2 switches

(AR/AD and AR/AE respectively) for the operation of the aileron boost relay /RL1 from either hydraulic system. The elevator boost relay /RL2 is operated in a similar manner via diodes /MR21 and /MR23.

38. When aileron and/or elevator boost is selected, the No.1 contact sets of the boost relays, /RL1/1 and RL2/1, operate in the respective control-loading systems (/220 and /222) to provide reduced scaling of the torsion bar signal fed to the demand amplifiers (para.12(2) and 17, respectively).

Chapter 2

TRIMMING SYSTEMS

List of Contents

List of Illustrations

Introduction

1. Trimming of the aircraft is achieved by electrically-operated, actuator-driven trim surfaces. The trim indicators and most of the control switches are positioned on the centre stand panel CB; pitch trim and emergency pitch trim disconnect switches are mounted, in duplicate, on the pilot's and co-pilot's control wheels.

2. The aircraft longitudinal (pitch) trim is obtained by variation of the tailplane angle of incidence. The pitch trim system includes a Mach trim compensator which, when selected, automatically corrects the aircraft trim when the aircraft is flying at speeds within the range 0·8 to 0·89 Mach. Aileron trim and rudder trim are achieved by conventional trimming tabs.

3. In the simulator, the trimming systems circuits contain actuators which are supplied with power from the aircraft busbars via circuit breakers and the trim controls. The actuator motors drive potentiometers which supply trimming signals to the flying controls and control loading system (Chap. 1) and to the trim indicators.

AILERON AND RUDDER TRIM CIRCUIT

4. The aileron and rudder trim systems are operated by inching trim-switches which control directly the sense of rotation of the associated actuator motors; the aileron and rudder trim indicators consist of ratiometer-type meters which are driven by twin-ganged potentiometers.

Aileron trim (/224)

5. The +27V supply from the main d.c. busbar is fed, via interconnection (1) and the AILERON TRIM CONT circuit breaker SG/118, to the circuit of amplifier 14AS/b/A1. The amplifier input signal is adjusted to the required aileron trim system response by potentiometer 14E/T9/RV22 and is disconnected by operated contact set 14E/T7/RL7/3 when the trimming system is disconnected (para. 20(2)). The amplifier output signal is available for connection to the aileron actuator motor 14AS/b/X1, via the two sections of the AIL trim switch CB/AN. The switch is biased to the centre-off position; operation of the switch to either "on" position connects the motor winding to the amplifier output and earth for the required direction of rotation.

6. The actuator motor shaft is coupled to ϕ_T potentiometers 14AS/b/RV1a and /RV1b which provide the energizing current, and earth return respectively, for the three windings of the AILERON trim indicator CB/AT.

Rudder trim (/224)

7. The circuit of the rudder trim system is similar to the aileron trim circuit. When changes in rudder trim are made by means of the RUD trim switch CB/AP, a positive or negative 27V d.c. supply is connected to the input of amplifier 14AS/c/A1 via contact set 14E/T7/RL20/1 which is operated under normal trimming conditions (para. 8). The amplifier output drives actuator motor 14AS/c/X1 in the direction

required, according to the polarity of the signal voltage selected by switch CB/AP.

8. The wipers of ganged potentiometers 14AS/c/RV1a and /RV1b, driven by the actuator motor, provide drive signals and earth return, respectively, for the RUDDER trim indicator CB/AQ, mounted on the cockpit centre stand. The +27V main d.c. busbar supply is connected to the wiper of potentiometer 14AS/c/RV1a via the RUDDER TRIM CONT circuit breaker SG/119, and to the coil of the "able to trim" relay 14E/T7/RL20 via released contact set /T7/RL7/4; relay /RL7 is operated in an emergency when the trimming systems are disconnected (para.20).

PITCH TRIM CIRCUIT

9. Trim in pitch is selected by either the pilot's or co-pilot's NOSE DN/NOSE UP switches, AQ/AB and AT/AB, respectively. The switches are mounted on the control wheels, and each switch consists of two parallel-connected sections which are spring-biased to the centre-off position. The switches are fed from the main d.c. busbar, and control a network of "pitch demand sensing" relays. The pitch trim indicator is driven by a computing loop which is fed with the nose up/nose down trim demand signals and q and M signals from the flight computer; the M signals provide automatic pitch trimming at higher airspeeds (0·8 to 0·89 Mach) when the Mach trim compensator (para.22) is selected.

10. The normal range of pitch trim available is from 6^{o} nose-down to 4^{o} nose-up. When flaps are selected (wing flaps system, Part 10, Chap.5), the nose-up trimming range is increased to 10^{o}. The actual trim angle is shown on the HORIZ STAB trim indicator CB/AG, on the centre stand.

11. Malfunction of the pitch trim system can be introduced by the flight instructor's STABILISER switch XF/AC/S3. When operated, this switch energizes the "nose-up" relays associated with the pitch trim switches, and thus causes an excessive nose-up trim condition.

12. The normal, manual, pitch trim selection, or the automatic Mach trim compensator control, can be cut-off by operation of the TRIM DISC switches AQ/AD and AT/AD, mounted on the pilot's and co-pilot's control wheels respectively. When operated, these push-button switches disconnect all drive signals from the pitch trim servo-motor circuits. In an emergency, pitch trim selection can be achieved by operation of the HOR STAB TRIM SYS switch CB/AH, which allows an immediate nose-up or nose-down trim to be selected by the EMER HOR STAB TRIM switch CB/AF. These two switches are situated on the cockpit centre stand. To reconnect the normal pitch trim system to the pitch trim servo motors (after operation of the TRIM DISC switches), the TRIM SYS RESET switch CB/AR must be operated.

Nose-up or nose-down trim selected (/225)

13. Provided that the main d.c. busbar supplies are available and the HOR STAB circuit breaker SG/120 makes, operation of the pilot's or co-pilot's pitch trim switches (AQ/AB or AT/AB), to the NOSE UP position energizes the coils of the "nose up or down selection" relays 14E/T7/RL3 and /RL19. Contact set /RL19/1 changes over, and the "nose up selected" relays, /RL1 and /RL15 are also energized These four relays are energized for the period of the trim switch operation; diode /MR4 prevents the operation of the "nose down selected" relays (para.14). Operated contact sets /RL15/1 and /2 isolate the energized relays from the "nose down" poles of the pilots' trim switches to ensure that if, for example, the pilot's switch is set to NOSE UP, the co-pilot's switch cannot select the circuit of the "nose-down" relays. Contact set /RL3/3 operates in the "mach trim compensator out" warning lamps (para.27(2)); the other contact sets of /RL1 and /RL3 function in the computing circuits of the pitch trim actuator (para.31 and 32).

14. Deflection of either or both pitch trim switches to the NOSE DN position energizes the "nose up or down selection" relays, /RL3 and /RL19, and the "nose down selected" relays, /RL2 and /RL18. The functions of the contact sets of these relays is similar to that for "nose up" selection (para.13), contact set /RL18/1 and /2 fulfilling the function of contact sets /RL15/1 and /2. Diode /MR5 prevents the operation of the "nose up selected" relays.

Stabilizer run-away (/225)

15. The stabilizer run-away condition, i.e., increasing nose-up attitude, can be selected by the flight instructor by operation of the STABILISER switch XF/AC/S3. When operated, this switch connects the main d.c. busbar supplies from diode 14E/T8/MR2 to the "nose-up or down selected" relays /RL3 and /RL19, and to the "nose up selected" relays /RL1 and /RL15 (para.13). These four relays are energized via released contact set /RL5/3 (of the "trim disconnect or emergency selected" relay /RL5, para.17) and the associated isolating diodes. The pilots' pitch trim switches, AQ/AB and AT/AB, are disconnected, as in para.13, and the nose-up condition is maintained until the emergency switch selection is made and operated contact set /RL5/3 disconnects the circuit of the STABILISER switch (para.17(7)), or until the STABILISER switch is reset to off.

Emergency trim selection (/225)

16. When the stabilizer run-away condition is introduced (para.15), the ensuing nose-up trim must be corrected by the selection of emergency pitch trim. The HOR STAB TRIM SYS switch CB/AH must be set to the EMER position, and the

emergency pitch trim selection can then be made by the NOSE UP/NOSE DOWN EMER HOR STAB TRIM switch CB/AF; switch CB/AF is connected, via operated contact set /RL5/1 (para. 17(5)), released contact set /RL6/2 (para. 20(4)), first section of CB/AH and the EMER TRIM CONT circuit breaker PP/37, to the essential d.c. busbar supplies. If the simulated aircraft has assumed a nose-up attitude, selection of CB/AF to NOSE DOWN will energize /RL3 and /RL19 and the two "nose-down selected" relays /RL2 and /RL18.

17. The second section of switch CB/AH routes the essential d.c. busbar supplies (from the TRIM DISC circuit breaker PP/38) to the "trim disconnect or emergency selected" relays /RL4 and /RL5 the contact sets of which provide the following functions:

(1) Contact set /RL4/1 operates in the circuit of the MACH TRIM COMP OUT warning lamps (para. 27)

(2) Operated contact set /RL4/2 disconnects the main d.c. busbar supplies from the pilots' pitch trim switches AQ/AB and AT/AB

(3) Operated contact set /RL4/3 disconnects the supplies to the "compensator on" relay /RL9 (para. 23)

(4) Operated contact set /RL4/4 disconnects the supplies from the "mach trim test on" relays /RL13 and /RL14 (para. 26)

(5) Operated contact set /RL5/1 connects switch CB/AF to switch CB/AH (first section) for selection of emergency pitch trim (para. 16)

(6) Operated contact set /RL5/2, in conjunction with operated contact set /RL6/3, disconnects the main d.c. busbar supplies to the "able to trim" relay /RL17 (para. 34)

(7) Operated contact set /RL5/3 removes the stabilizer run-away condition (para. 15).

18. The third section of switch CB/AH connects, via the EMER pole, the coil of relay /RL6 to the TRIM DISC switches (para. 20)when the normal pitch trimming system is disconnected.

19. Subsequent pitch trim can be accomplished by further use of switch CB/AF, or by the normal pitch trim selectors AQ/AB, AT/AB (para. 13). In certain circumstances it is necessary to disconnect the pitch trimming system, and control the simulated aircraft directly by the flying controls (para. 20).

Trim disconnect and reset (/225)

20. When the aircraft is in a dangerous attitude and the use of emergency pitch trim (para.16) is not sufficient for fast recovery, the trimming systems can be disconnected by means of the TRIM DISC switches AQ/AD and/or AT/AD on the control wheels. Operation of either of the TRIM DISC switches connects the essential d.c. busbar supplies, from the TRIM DISC circuit breaker PP/38, to the "stabilizer trim and aileron, rudder trim disconnect" relay /RL7, and to the "trim disconnect or emergency selected" relays /RL4 and /RL5 which, if not energized via the EMER pole of switch CB/AH (para.17), become energized via self-holding contact set /RL7/1. The coil of "trim disconnect in emergency" relay /RL6 can also be energized, via the EMER pole of switch CB/AH and the relay will self-hold via /RL6/1. Operated contact sets of these relays provide the necessary isolation of the following circuits:

(1) Contact set /RL7/2 disconnects the supply to the "Mach trim comp. out, lights compensator relay on" relay /RL10 (para.23)

(2) Contact set /RL7/3 and /4 disconnect power to the aileron trim actuator circuit (para.5) and to the "able to trim" relay /RL20 (para.8), respectively

(3) The functions of the contact sets of relays /RL4 and /RL5 are described in para.17

(4) Contact set /RL6/2 disconnects the essential d.c. supplies to switch CB/AF (para.16)

(5) Contact set /RL6/3, in conjunction with operated contact set /RL5/2 (para.17(6)),disconnects the essential d.c. busbar supplies to /RL17 (para.34).

21. The trimming systems are inoperative, even after the release of the spring-biased TRIM DISC switches until the flying conditions revert to normal, and the trimming systems are reselected by use of the TRIM SYS RESET switch CB/AR. Setting this switch to NORMAL disconnects power to the TRIM DISC switches and to relays /RL4, /RL5, /RL6 and /RL7. If the fault subsequently has been cleared (instructor's STABILISER switch reset to off), normal trimming procedure can be implemented.

Mach trim compensator (/225)

22. The Mach trim compensator consists of a fully automatic pitch trimming system which trims the aircraft nose-up, at high Mach numbers, as an 'overspeed' precaution.

23. The Mach trim compensator is selected by setting the MACH TRIM COMP CONTL switch CF/AM to ON. Provided that the faultable MACH TRIM DC CONTROL circuit

breaker SL/61 (in the aircraft electrical system, Part 10, Chap.1) is made, the main d.c. busbar supplies are routed, via operated contact set 13G/T5/RL17/2, to the compensator control relays. The "compensator on" relay 14E/T7/RL9 is energized via released contact set /RL4/3 (para.17(3)) and the MACH TRIM AC CONTROL circuit breaker SL/60; the "Mach trim comp. out, lights compensator on" relay /RL10 is energized, via released contact set /RL7/2 (para.20(1)), and the supply is available via released contact set /RL12/1 to the circuit of the Mach trim compensator "test on" relays (para.25). Operated contact set /RL10/1 extinguishes the two MACH TRIM COMP OUT warning lamps CF/AG and SA/AM (para.27), and contact set /RL9/1 connects the M signal to the input of pitch trim motor drive-amplifier 14EH/a (para.32) to adjust the pitch trim angle in relation with the actual Mach number.

<u>Mach trim compensator test</u> (/225)

24. The Mach trim compensator can be tested, on the ground, for correct function by operation of test switch CF/AL which is labelled GROUND ONLY - MACH TRIM COMP TEST. Setting this switch to the TEST position starts an automatic test cycle during which approximately 3^o of nose-up trim are introduced and indicated on the HORIZ STAB trim gauge. The pitch trim reverts to 0^o before the test cycle is completed. Setting switch CF/AL to the OFF position does not interrupt the test cycle (approximately 25 seconds); the test can be stopped only by switching OFF the master compensator switch CF/AM.

25. The test circuit is energized via the MACH TRIM COMP CONTL switch CF/AM (para.23), switch CF/AL set to TEST and released contact set /RL4/4 (para.17(4)). The "Mach trim test on" relay /RL13 is energized immediately, and relay /RL16 is energized via operated contact set /RL13/1; relay /RL16 is maintained operated by its contact set /RL16/1 which is connected to switch CF/AM, thus by-passing switch CF/AL. Diode /MR26 ensures that relay /RL13 is then also held energized and that the "$\frac{1}{2}$ sec. Mach trim test on" relay /RL14 is energized after a 0·5 second delay given by time constant 14E/T9/R16 and /C3.

26. Operated contact set /RL13/3 connects the supply from diode /T8/MR6 to the MACH TRIM COMP OUT warning lamps which light for 0·5 second until operated contact set /RL14/3 disconnects the supply line. Contact sets /RL13/2 and /RL14/1 provide a 3^o nose-up test signal to the computing circuit of the pitch trim actuator and gauge (para.33), and contact sets /RL13/4, /RL16/2 and /RL16/3 complete the feedback loop of the pitch trim actuator drive amplifiers (para.36). Simultaneously, operated contact set /RL14/2 feeds the +50V supply to the "Mach trim test on" relay /RL9 which energizes after a delay (approximately 15 seconds) given by time constant /T9/R15 and /C4. The 15-second delay represents the test period at the end of which relay /RL9 operates, and operated contact set /RL9/1 disconnects the supply to the "Mach trim test on" relay /RL16 which de-energizes. If switch CF/AL has been returned to the OFF position, relays /RL13 and /RL14 will also de-energize at this time, and the test sequence is completed.

Mach trim compensator out lights (/225)

27. The two MACH TRIM COMP OUT lamps SA/AM and CF/AG provide warning, when lit, that the Mach trim compensator is not selected, or is not operating. Lighting of the lamps is due to one of the following causes:

(1) Mach trim compensator off; the lamp supply from the essential d.c. busbar is routed via the MACH TRIM WARN LT circuit breaker SL/59, diode 14E/T8/MR1 and released contact set /T7/RL10/1 (para.23); the press-to-test switches of the lamps are also supplied from diode /T8/MR1.

(2) Manual trim used and overriding the function of the switched on Mach trim compensator if the airspeed is in excess of 0·78 Mach; relay /RL8 is energized via M switch card 13CS/RV20, and operated contact sets /RL8/1 and /RL3/3 ("nose-up or nose-down selected") complete a second power line to the lamps.

(3) Mach trim compensator on, but trimming systems are disconnected (by switches AQ/AD or AT/AD, para.20); in this instance, relay /RL7 (para.20) is energized, relay /RL10 is therefore de-energized, and released contact set /RL10/1 connects the lamps as in sub-para. (1).

(4) The third lamp supply line, via operated contact sets /RL10/1, switch CF/AM and /RL4/1 (Mach trim compensator on, but emergency trimming selected), is now redundant, because these two contact sets cannot be operated simultaneously.

28. The two lamps are also lit for 0·5 second when the Mach trim compensator tests are made and switch CF/AL (para.24) is made. The lamp supplies are then obtained from the main d.c. busbar supplies via operated contact set /RL13/3 and released contact set /RL14/3 (para.26). Contact set /RL14/3 operates 0·5 second after the test is started and extinguishes the lamps.

Pitch trim actuator and indicator (/226)

29. The pitch trim actuator motor 14AS/a/M is driven by amplifier 14EH/a and power amplifier 14AS/a. The pitch rate computing circuit, at the input of amplifier 14EH/a, consists of a summing network of the pitch demand signals, flight computer signals and a negative feedback signal from amplifiers 14GE/a and 14GE/b (para.36).

30. The manual pitch trimming rate is given by the following equation:

$$\text{Trim rate} = \pm\left[\,0{\cdot}55 - 3{\cdot}4\ f_{1c}(\eta)\ q\,\right] \text{degrees/second}$$

where $3{\cdot}4\ f_{1c}(\eta)\ q \leqslant 0{\cdot}55.$

31. The signal inputs to summing amplifier 14EH/a correspond to the terms of the trim rate equation (when under manual trimming) as follows:

(1) The first term represents the nose-up or nose-down trim demand selected by the manual trimming controls. Contact sets 14E/T7/RL1/1 and /3 are operated when nose-up is selected and a negative signal, scaled by /T9/R3 is fed to the amplifier input, via /T9/MR2. Similarly, contact set /RL2/1 and /3 connect a positive (nose-down) signal via /T9/MR1.

(2) The second term includes the correction due to dynamic pressure q and due to the actual elevator deflection angle η. For nose-up demands, operated contact set /T7/RL1/2 supplies the +q signal (from the drag loop system, Part 8, Chap.2) to η potentiometer XF/AQ/RV1c which is driven by the elevator control of the control loading system (Chap.1). The potentiometer wiper output is fed via /RL1/3 and /T9/MR2 (as in sub-para.(1)) to the summing point. Similarly, the nose-down signal is obtained via operated contact set /RL2/2 and /3.

32. When the pitch trimming system is under automatic control of the Mach trim compensator (para.22) a signal, proportional to the Mach number, is obtained from M potentiometer 13CS/RV21 which is energized via operated contact set /RL9/1. Relay /RL9 is energized when the compensator is switched on (para.23). The potentiometer wiper output is routed to the summing point via /T9/R5 provided that the manual trim selection is not made and contact set /RL3/1 is released (para.13).

33. During ground tests of the Mach trim compensator (para.25 and 26), the 3° nose-up signal is obtained by the discharge of capacitor /T9/C2 into the summing point. When the MACH TRIM COMP TEST switch CF/AL is set to TEST, operated contact set /RL13/2 supplies the charging current, via /T9/R7 to /T9/C2; contact set /RL14/1 operates with a 0·5-second delay and provides the discharge path, via released contact set /RL3/4 and /T9/R6, to the input of amplifier 14EH/a. The "nose-up or down selected" relay /RL3 is energized during manual pitch trimming procedure (para.13).

34. The appropriate pitch demand signals are applied to the input of amplifier 14EH/a together with the negative feedback signal, as applicable, from amplifier 14GE/b (para.36). The output of 14EH/a is fed, under normal trimming conditions, via operated contact sets /RL17/1 and /RL12/1 to the actuator drive amplifier 14AS/a and to the actuator motor 14AS/a/M. The "able to trim" relay /RL17 (/225) is energized only when "emergency trim" or "trim disconnect" are not selected and contact sets /RL6/3 and /RL5/2 are released (para.20 and 17 respectively). The "trim less than 4°" relay /RL12 is operated by the trim angle discriminator (para.38) to limit the nose-up trim to 4° (para.10). When trim demands in excess of this limit are made, contact set /RL12/1 is released, and the positive "nose-up" signals are prevented by diode /T9/MR3 from reaching the power amplifier Extension of the

31. The signal inputs to summing amplifier 14EH/a correspond to the terms of the trim rate equation (when under manual trimming) as follows:

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(2) The second term includes the correction due to dynamic pressure q and due to the actual elevator deflection angle η. For nose-up demands, operated contact set /T7/RL1/2 supplies the +q signal (from the drag loop system, Part 8, Chap. 2) to η potentiometer XF/AQ/RV1c which is driven by the elevator control of the control loading system (Chap. 1). The potentiometer wiper output is fed via /RL1/3 and /T9/MR2 (as in sub-para. (1)) to the summing point. Similarly, the nose-down signal is obtained via operated contact set /RL2/2 and /3.

32. When the pitch trimming system is under automatic control of the Mach trim compensator (para. 22) a signal, proportional to the Mach number, is obtained from M potentiometer 13CS/RV21 which is energized via operated contact set /RL9/1. Relay /RL9 is energized when the compensator is switched on (para. 23) The potentiometer wiper output is routed to the summing point via /T9/R5 provided that the manual trim selection is not made and contact set /RL3/1 is released (para. 13).

33. During ground tests of the Mach trim compensator (para. 25 and 26), the 3^{o} nose-up signal is obtained by the discharge of capacitor /T9/C2 into the summing point. When the MACH TRIM COMP TEST switch CF/AL is set to TEST, operated contact set /RL13/2 supplies the charging current, via /T9/R7 to /T9/C2; contact set /RL14/1 operates with a 0·5-second delay and provides the discharge path, via released contact set /RL3/4 and /T9/R6, to the input of amplifier 14EH/a. The "nose-up or down selected" relay /RL3 is energized during manual pitch trimming procedure (para. 13).

34. The appropriate pitch demand signals are applied to the input of amplifier 14EH/a together with the negative feedback signal, as applicable, from amplifier 14GE/b (para. 36). The output of 14EH/a is fed, under normal trimming conditions, via operated contact sets /RL17/1 and /RL12/1 to the actuator drive amplifier 14AS/a and to the actuator motor 14AS/a/M. The "able to trim" relay /RL17 (/225) is energized only when "emergency trim" or "trim disconnect" are not selected and contact sets /RL6/3 and /RL5/2 are released (para. 20 and 17 respectively). The "trim less than 4^{o}" relay /RL12 is operated by the trim angle discriminator (para. 38) to limit the nose-up trim to 4^{o} (para. 10). When trim demands in excess of this limit are made, contact set /RL12/1 is released, and the positive "nose-up" signals are prevented by diode /T9/MR3 from reaching the power amplifier Extension of the

Chapter 3

FLIGHT SYSTEMS (COLLINS, SPERRY)

List of Contents

List of Tables

List of Illustrations

List of Illustrations (Cont'd.)

Introduction

1. The simulator is equipped with two alternative flight systems. The two installations, the indicators of which are physically interchangeable, are the Collins type FD-105 integrated flight system (IFS) and the Sperry integrated instrument system (IIS). Pilot and co-pilot are provided with identical instruments, which display aircraft attitude, heading, and radio-navigational course information. Figures 1 and 2 show, respectively, the information flow between the sub-units of the Sperry system, and between those of the Collins system.

2. The master heading instrument is the Sperry C-6F Gyrosyn compass indicator, which displays magnetic heading, contains radio-magnetic bearing indicator pointers, and supplies the flight systems instruments with repeat-heading signals. Two C-6F compass indicators are fitted, one on the pilot's instrument panel and one on the co-pilot's instrument panel. The C-6F compass indicators provide the heading data for both Collins and Sperry flight systems, irrespective of the flight system selected.

3. In the aircraft installation, magnetic heading information is supplied to the compass indicators from a flux valve and a directional gyro; in the simulator, however, the compass cards are positioned by signals from synchros in the heading system (Part 8, Chap.8).

4. In the simulator attitude information is supplied to the flight systems in the form of signals from synchros positioned by pitch and bank actuators. These actuators are controlled by signals derived from the flight computer. Simulation of vertical gyro erection delay is also provided.

5. Attitude demand indications, for lateral and vertical guidance, are controlled by signals derived from the heading, VOR and ILS computation systems in conjunction with the Collins steering computer or the Sperry IIS computer. The ILS/VOR systems (Part 12, Chap.6) provide course and glidepath-deviation signals in simulation of those supplied by the radio-navigational receivers in the actual aircraft installation.

6. The pilot's and co-pilot's flight system instruments are identical; in the following description, reference is made mainly to the pilot's instruments.

Note...
Certain indications given by the various flight systems instruments are not described in this chapter because such description is contained in other chapters. These are the RMI system (Part 12, Chap.9), the ILS/VOR systems (Part 12, Chap.6) and the DME system (Part 12, Chap.10). For a full description of the flight systems aircraft installation, reference should be made to the relevant Collins or Sperry manual.

PITCH AND BANK SYNCHRO DRIVE (/216)

7. The pitch and bank actuators drive synchros that control the attitude indications of the flight systems instruments. The bank actuator 13AS/c/X1 is positioned (from -60^{o} to $+60^{o}$) in accordance with the computed angle of bank, β. The angle of pitch of the aircraft is the sum of the angle of incidence α and the angle between the flight path and the horizontal, n_1. Because n_1 is expressed in radians and α in degrees, the pitch actuator 13AS/b/X1 is positioned (from -35^{o} to $+52^{o}$) in accordance with the equation:

$$\text{Pitch} = \alpha + 57{\cdot}6 \; n_1$$

8. Relays 13E/T1/RL18 and /RL19 are energized if the +27V representing either the essential a.c. or the No.1 a.c. busbar is present. The terms $-\alpha$ and $-n_1$ are fed to the summing junction of amplifier 13EF/a via normally-operated contact sets /RL18/1 and /2, respectively. The output of 13EF/a feeds a power amplifier 13AS/b/A1 which drives the pitch actuator; the input to the power amplifier is connected via normally-operated contact set /RL18/4.

9. Positional potentiometer 13AS/b/RV1, coupled to the shaft of the pitch actuator, causes the pitch servo-loop to drive to a null.

10. During pre-stall conditions, the $-n_1$ signal from the flight computer tends to increase and to produce nose-up attitude. This tendency is opposed and a nose-down attitude is achieved, at the point of stall, by feeding $+n_1$ via contact set /RL16/1 (operated when stall conditions are present) and via an R-C shaping network, to the input of 13EF/a. Thus, the required pitch changes during stall are presented on the instruments.

11. The bank actuator 13AS/c/X1 is controlled by a servo loop similar to that of the pitch actuator. Normally, only one input, $+\beta$, is required and is fed to the input of computing amplifier 13EF/b via operated contact set /RL19/1. The output of 13EF/b feeds a power amplifier, 13AS/c/A1, via operated contact set /RL19/3; the output of the power amplifier drives the bank actuator.

12. When the simulator is first switched on, and prior to the switching-on of aircraft a.c. supplies, relays /RL18 and 19 are in the de-energized state. Thus, capacitors /T6/C1 and /T6/C2 are charged, initially, to +50V via released contact sets /RL18/3 and /RL19/2. When either the essential or No.1 a.c. busbar supplies are subsequently switched on, /RL18 and /RL19 operate and the capacitors discharge into the amplifier inputs, off-setting the bank and pitch actuators. The capacitors discharge in approximately 3 minutes, at the end of which time the actuators take up the position demanded by the flight computer. The capacitor circuits thus simulate the gyro erection-time.

13. Should both a.c. supplies be subsequently switched off or failed, /RL18 and /RL19 de-energize, their contact sets disconnect the flight computer input signals, freeze the actuators in the position reached at the point of failure, and the capacitors start to charge. If the a.c. supplies are restored before the capacitors are fully charged, the indicators will take up an intermediate off-set position, simulating a partially run-down gyro. During failure periods the amplifiers are effectively inhibited by the connection of 100-kilohm feedback resistors via operated contact sets /RL18/4 and /RL19/3.

14. The actuators each drive two synchros, 13AS/b/TX1 and /TX2 (pitch), and 13AS/c/TX1 and /TX2 (bank). These synchros are shown on the relevant system diagrams.

SPERRY INTEGRATED INSTRUMENT SYSTEM

15. The Sperry IIS comprises a C-6F Gyrosyn compass indicator, an HZ-4 horizon flight director indicator and an R-4A pictorial deviation indicator. These instruments are duplicated, and are fitted to pilot's and co-pilot's instrument panels. Also included in the Sperry IIS are the IIS computer, the mode selector, roll-, pitch-, heading- and compass- amplifiers, and an instrument amplifier.

16. The essential a.c. and d.c. busbars supply the port (pilot's) flight systems and the No.1 main a.c. and main d.c. busbars supply the starboard (co-pilot's) instruments The complete IIS fails in the event of loss of any of the following supplies:

(1) 26V, 400c/s a.c.
(2) 115V, 400c/s a.c.
(3) Both a.c. busbar supplies (+27V d.c.)
(4) Both d.c. busbar supplies (+27V d.c.).

Partial instrument failures can be introduced as described in the following paragraphs.

C-6F compass indicator (/352)

17. A synchro, 22AF/A/TX1, driven by the heading servo-motor (Part 8, Chap.8), provides the initial heading signal. This signal is fed to the port C-6F synchro-receiver, the stator of which is connected mechanically to the synchronization knob, at the bottom right-hand corner of the instrument. The heading error signal is fed from the rotor of the synchro-receiver to the Sperry No.1 compass amplifier, the output of which drives the compass motor to null the compass servo-loop, thus driving the heading card of the port C-6F compass indicator AA/AG to follow the heading servo.

18. A second error synchro, the stator of which is fed with the initial heading signal, feeds a type ZDA amplifier 21AQ. The rotor of this synchro is positioned by the compass motor. The output of the p.s.r. section of 21AQ is fed to the SLAVE COMPASS/DG switch AA/AP. When this switch is set to the SLAVE COMPASS position, the p.s.r. output is fed to the coil of a "dot-cross" annunciator flag in the top right-hand corner of the C-6F indicator. If the compass card is not synchronized with the initial heading signal, a signal is fed to the p.s.r. The resultant d.c. output of the p.s.r. energizes the coil of the annunciator which then shows either a dot or a cross, depending on the polarity of the p.s.r. output. The synchronization knob can then be turned in the direction indicated on the knob to null the p.s.r. output and thus centralize the annunciator flag.

19. When the SLAVE COMPASS/DG switch is set to DG, the coil of the annunciator flag is disconnected, and the compass then functions as a direction indicator.

20. Failure of the port C-6F compass system occurs if the COMPASS NO.1 115 VAC circuit breaker PH/123 is tripped, or when the COMP 1 fail switch XF/AK/S9 is operated Either of these conditions releases XX/CX/RL6, contact set No.1 of which releases and disconnects the 115V, 400c/s supply to the No.1 compass amplifier. The absence of the 115V, 400c/s supply causes the OFF warning flag to appear within the C-6F.

21. The starboard C-6F functions similarly to the port C-6F. The starboard compass fails if the COMPASS No.2 115 VAC circuit breaker (faultable) SM/13 is open-circuited (electrical system, Part 10, Chap.1), or if the COMP 2 switch XF/AK/S16 (faultable circuit breaker) is operated. Either of these fault conditions de-energizes relay 13G/T5/RL15 (electrical system, Part 10, Chap.1), and, consequently, XX/CX/RL7 is de-energized by contact set /RL15/2. Contact set /RL7/1 disconnects the 115V, 400c/s supply from the No.2 compass amplifier and the OFF flag appears in the starboard (co-pilot's) C-6F compass indicator.

22. The C-6F compasses also contain the RMI pointers (RMI system, Part 12, Chap.9) and heading-transmitting synchros for the other instruments in the Sperry IIS or the Collins IFS.

Heading (/353)

23. Repeat-heading is displayed on the Sperry R-4A pictorial deviation indicators (PDI) AA/AW (pilot's) and AB/AV (co-pilot's).

24. A heading synchro in the port C-6F feeds an error synchro in the port PDI. The resultant error signal is fed from the rotor winding of the synchro in the PDI to the Sperry No.1 heading amplifier XX/CH. The output of this amplifier drives a motor in the PDI which positions the PDI heading card and also drives the error synchro to null. Thus, the PDI heading card follows the C-6F compass card.

25. The heading card of the port PDI fails if:

(1) The FLIGHT DIR NO.1 HDG AC circuit breaker (faultable) PH/126 is tripped
(2) The FLT DIR 1 HEADING switch XF/AK/S14 (faultable circuit breaker) is operated
(3) The COMPASS NO.1 VAC circuit breaker PH/122 is tripped.

Circuit breaker PH/122 is shown on drawing /339 (RMI system, Part 12, Chap.9). Either of conditions (1) or (2) causes relay 13G/T5/RL9 (faultable circuit breakers, electrical system, Part 10, Chap.1) to be de-energized. Contact set /RL9/2 releases and de-energizes XX/CX/RL8, the No.1 contact set of which then disconnects the 115V, 400c/s, supply from pin 1 of the Sperry No.1 heading amplifier The heading card is thus immobilized and the OFF flag appears in the left-hand side of the PDI. If PH/122 is open-circuited, XX/CX/RL4 (/339) is de-energized and contact set XX/CX/RL4/1 disconnects the 26V, 400c/s, supply from the port C-6F compass indicator AA/AG. The 26V, 400c/s, supply feeds the compass heading-transmitting synchros; thus, if PH/122 is tripped, the repeat-heading on the port PDI fails.

26. The heading card of the starboard PDI fails, and its OFF flag appears, if the FLT DIR NO.2 HDG circuit breaker SM/2 is tripped. Relay XX/CX/RL9 de-energizes and contact set XX/CX/RL9/1 disconnects the 115V, 400c/s, supply from the Sperry No.2 heading amplifier. Circuit breaker SM/2 is not faultable. The heading card of the starboard PDI is immobilized if the COMPASS NO.2 26 VAC circuit breaker SM/14 (RMI system, Part 12, Chap.9) trips, removing the 26V, 400c/s, supply for the starboard C-6F compass heading-transmitting synchros.

Roll (/354)

27. Roll attitude is presented on a servo-driven sphere in the HZ-4 horizon flight director indicator AA/AV. Roll angle is represented by the degree of rotation of

the sphere, displayed by an index against a fixed scale and by the white horizon bar painted on the sphere.

Note...
On drawing /354, the roll index is annotated thus: ROLL BAR.

28. A bank signal is obtained from synchro 13AS/c/TX1 that is driven by the bank actuator (para.14). The bank synchro feeds signals to an error synchro in the port horizon flight director. The error signal induced in the error synchro rotor winding is connected, via contact set XX/CX/RL16/2 (normally-operated, para.35) to the Sperry No.1 roll amplifier XX/CH. The amplifier output controls a motor that drives the sphere in the roll plane and which also nulls the roll error synchro. Thus, the flight director follows the motion of the bank actuator.

29. The roll index is inoperative if either the FLIGHT DIR NO.1 ATT AC circuit breaker PH/127 is tripped, or a vertical-gyro failure occurs (para.35). If PH/127 trips, relay XX/CX/RL10 de-energizes and contact set /RL10/1 disconnects the 115V, 400c/s, from the No.1 roll amplifier. A vertical-gyro failure (drawing /355 and para.35) causes contact set XX/CX/RL16/2 to release and to disconnect the rotor winding of the error synchro in the flight director.

30. The bank synchro 13AS/c/TX1 also feeds a synchro in the starboard horizon flight director indicator, which operates in an identical manner to the port instrument. The roll index of the starboard flight director fails if:

(1) The FLT DIR NO.2 ATT circuit breaker SM/3 is tripped
or (2) A vertical-gyro failure occurs (para.35).

<u>Pitch</u> (/355)

31. Pitch attitude is presented on the sphere of the horizon flight director indicator and is indicated by the relative displacement of the white horizon line, and of numbered pitch index lines painted on the sphere, with respect to a fixed miniature airplane symbol.

Note...
On drawing /355, the pitch index is annotated thus: PITCH BAR.

32. Synchro 13AS/b/TX1, driven by the pitch actuator, supplies the initial pitch signal to an error synchro in the port flight director indicator AA/AV. The resultant error voltage is fed, via normally-operated contact set XX/CX/RL16/1 (para.35) and a sphere pitch trim potentiometer, to the Sperry No.1 pitch amplifier XX/CH.

33. The output of the pitch amplifier controls the pitch motor, in the flight director, that drives the sphere in the pitch plane and which also nulls the pitch error synchro. Thus, the pitch index follows the motion of the pitch actuator.

34. The stator of pitch synchro 13AS/b/TX1 is off-set by 3^{o} with respect to the actuator dial zero to achieve a 3^{o} nose-down bias of the horizon. The horizon can also be preset to any required position by use of the sphere pitch-trim knob, located at the bottom right-hand corner of the HZ-4 flight director indicator. The knob controls a potentiometer, the setting of which determines the level of pitch error voltage fed to the pitch amplifier.

35. The input to the pitch amplifier is disconnected, and the horizon indication lost, if the coil of relay XX/CX/RL16 (and of parallel-connected /RL17, para.65) is de-energized and, consequently, contact set /RL16/1 is released, by one of the following conditions:

(1) VERT GYRO NO.1 AC circuit breaker PH/131 tripped
(2) VERT GYRO 1 fail switch XF/AK/S6 operated
(3) VERT GYRO NO.1 DC circuit breaker PH/132 tripped, and contact set XX/CX/RL15/1 consequently released.

Any of conditions (1), (2) or (3) also causes the G (gyro) warning flag to appear in the bottom left-hand section of the HZ-4 indicator (para.45). Contact sets of XX/CX/RL1 operate in the Collins pitch and roll systems to control the inputs to the amplifiers of the associated Collins instruments when the Collins system is in use.

36. The pitch synchro also feeds a synchro in the starboard horizon flight director indicator, which operates in an identical manner to the port instrument. The horizon and the pitch scale of the starboard flight director fails if:

(1) VERT GYRO NO.2 AC circuit breaker SM/5 is tripped
(2) VERT GYRO 2 fail switch XF/AK/S7 is operated
(3) VERT GYRO NO.2 DC circuit breaker SM/6 is tripped, and contact set XX/CX/RL18/1 consequently is released
(4) FLT DIR NO.2 DC circuit breaker SM/1 is tripped.

Conditions (1), (2) and (3) cause the G warning to be revealed in the starboard flight director.

Attitude (/356)

37. The vertical and horizontal attitude director bars of the HZ-4 indicators present flight direction demand data to the pilot and co-pilot. The attitude director

bars indicate the aircraft attitude that is required to attain (and maintain) a preselected flight condition.

38. The Sperry IIS computer, fitted in position XX/CG, controls the attitude directors in accordance with the setting of the Sperry mode selector switch on panel AC/CJ. The attitude director bars of both port and starboard HZ-4 indicators are connected in parallel and are controlled by a single IIS computer and one mode selector. The signals fed to the computer are shown in Table 1.

TABLE 1

Sperry IIS computer inputs

Signal:	Source:
Bank	Bank synchro 13AS/c/TX1, drawing /354
Pitch	Pitch synchro 13AS/b/TX1, drawing /355
Glidepath deviation	21B/RV54, drawing /327 (ILS/VOR systems, Part 12, Chap.6)
VOR or localizer deviation	21B/RV74, drawing /327 (ILS/VOR systems, Part 12, Chap.6)
Heading	Heading-error synchro via a transformer, in the port Sperry PDI, AA/AW.

39. The computer outputs are fed to the coils of the attitude directors via contacts of the mode selector switch. The indications given by the attitude director are shown in Table 2.

TABLE 2

Sperry attitude indications

Mode selector:	Function:
SB (stand-by)	Power on, but attitude directors inoperative and biased out of view.
BL (blue left)	Reversal of VOR or localizer demand signals in order to give correct attitude direction (on vertical pointer) when flying on a reciprocal heading.
FI (flight instruments)	Radio signals are not connected; the horizontal attitude director then functions as an artificial horizon, and the vertical attitude director indicates only heading and bank demand.
VOR LOC (VOR/localizer)	In this mode, the attitude directors display demand data relating to heading and bank, VOR/localizer deviation, and glidepath deviation. (BL is similar, but with azimuth display reversed).
APP (approach)	In this mode the heading, bank, and glidepath deviation signals are switched out, leaving only the radio azimuth demand signal (VOR/LOC) displayed by the vertical director. (The mode selector is normally set to this position by the pilot when the aircraft has passed the outer marker, inbound and on-course).
GA (go around)	Vertical pointer becomes centralized and horizontal pointer moves above the airplane symbol to give the correct indication for overshoot.

40. The IIS computer produces vertical and horizontal attitude demand signals as described in para.41 to 44.

41. A signal, proportional to the difference between actual heading and the course selected by the course cursor on the PDI, is fed from the PDI to the computer. This heading error signal produces a displacement of the vertical director to indicate the degree and direction of turn required to fly the selected course.

42. As the aircraft is banked into the turn, a signal from bank synchro 13AS/c/TX1 is produced and fed to the computer to null the bank demand signal fed to the vertical director. The vertical director then remains centralized throughout the turn, until the required heading is attained. As the heading error signal decreases the vertical director moves away from centre to demand opposite bank. The pilot then straightens the aircraft out of the turn and the vertical director centralizes once more.

43. When the mode selector is set to VOR/LOC, the vertical director is positioned in response to both heading and VOR/LOC deviation signals. The VOR/LOC deviation signal is routed to the computer from the ILS/VOR systems (Part 12, Chap.6) via the mode selector. In addition, the glidepath deviation signal is fed from the ILS/VOR systems to the IIS computer. The horizontal director displays the degree of pitch correction that must be applied to keep the aircraft on the selected glidepath. The glidepath deviation signal is nulled with a signal from the pitch synchro 13AS/b/TX1 to centralize the horizontal director when the correct glide slope is attained.

44. A flight director TRIM knob is provided on the mode selector panel. Turning this knob adjusts a potentiometer which feeds a biasing signal to the IIS computer. Trim is thereby applied to the pitch signal sent from the computer to the horizontal directors in both port and starboard HZ-4 indicators.

45. The gyro (G) warning flag (in the HZ-4 indicator) is held out of view provided that none of the following failure conditions occur:

(1) VERT GYRO NO.1 AC circuit breaker PH/131 tripped
(2) VERT GYRO 1 fail switch XF/AK/S6 operated
(3) VERT GYRO NO.1 DC circuit breaker PH/132 tripped.

Any of the conditions (1), (2) or (3) releases XX/CX/RL16 (drawing /355); contact set XX/CX/RL16/3 (normally-operated) then disconnects the +28V supply from the controlling coil of the flag, which moves into view to reveal the G warning. An identical system operates in the starboard HZ-4 indicator, and is controlled by contact set XX/CX/RL19/3.

46. FD warning markers in both HZ-4 indicators, are brought into view if a power failure occurs. The power for the FD warning flags comes from the

IIS computer.

47. The 115V, 400c/s, supply is fed to the IIS computer via normally-operated contact sets XX/CX/RL10/2 and XX/CY/RL12/1 (para.64). Relay /RL10 is normally energized from the essential a.c. busbar via circuit breaker PH/127 (/354), and /RL12 is energized via the normally-operated poles of the IFS ATT 1 fail switch XF/AK/S8 (/360). The +28V a.c. supply is fed to the IIS computer via normally-operated relay contact set XX/CX/RL13/2 and the mode selector. Relay /RL13 is energized from the essential d.c. busbar via circuit breaker PH/125 (/355).

Note...
The G and FD warning flags also appear if failure of the aircraft electrical supplies occurs.

COLLINS INTEGRATED FLIGHT SYSTEM

48. The Collins IFS FD-105 consists of two flight instruments, a steering computer, and an instrument amplifier. The flight instruments are the 329B-4A approach horizon indicator and the 331A-4A course indicator.

49. As in the instance of the Sperry IIS, the Collins IFS ceases to function when any of the aircraft electrical supplies fail.

Heading (/357)

50. With the Collins IFS in use, repeat-heading is displayed on the Collins 331A-4A course indicators AA/AH (pilot's) and AB/AF (co-pilot's).

51. A heading synchro in the port Sperry C-6F compass indicator feeds an error synchro in the port course indicator. Repeat-heading indication is achieved in a similar manner to that of the Sperry heading system (para.24). In addition, the Collins heading system fails as described in para.25 and 26; the 115V, 400c/s, supply to the Collins No.1 and No.2 instrument amplifiers is controlled by contact sets XX/CX/RL8/2 and /RL9/2, respectively.

Roll (/358)

52. Roll attitude is presented, in the Collins approach horizon indicator, by means of a bank pointer and horizon line painted on a disc. The bank pointer is similar in appearance to the roll index in the Sperry horizon flight director indicator (para.27).

53. The Collins roll system is similar in operation to the Sperry roll system and is subject to failures as described in para.29 and 30.

Pitch (/359)

54. Pitch attitude is presented in the Collins approach horizon, by means of a pitch bar that moves in a vertical plane above and below the centre of the instrument to show nose-up or nose-down attitude. A pitch trim knob, fitted at the bottom left-hand corner of the instrument, permits manual adjustment of the pitch bar when the HDG mode is selected on the HDG/ILS switch (para.58).

55. The Collins pitch system is similar in operation to the Sperry pitch system (para.32), except that the pitch synchro 13AS/b/TX2, which controls the Collins pitch system, has no preset bias. The Collins pitch system is subject to the failure conditions described in para.35 and 36.

Attitude (/360)

56. The Collins attitude systems supply attitude demand signals to the steering pointers in the approach horizon indicators.

57. Unlike the Sperry attitude system, the port and starboard Collins IFS instruments are each provided with independent computers (steering computers), instrument amplifiers and mode selection switches. The two Collins attitude systems are identical and only the one associated with the pilot's instruments is described.

58. The steering computer associated with the pilots instruments is fitted in position XX/CC and controls the steering pointer of the port approach horizon indicator in accordance with the setting of the HDG/ILS switch on the indicator AA/AE. The signals fed to the steering computer are shown in Table 3.

59. Selected heading for the HDG mode is provided by rotating the HEADING selector knob on the course indicator to the desired heading. The selected heading is displayed on the heading card by the heading marker, which rotates in synchronism with the heading card after being set. Deviation from the selected heading, shown by a difference between the heading marker and the lubber line, produces the heading error signal (referred to in Table 3) which is fed to the steering computer.

TABLE 3

Collins steering computer inputs

Signal:	Source:
Bank	Bank synchro 13AS/c/TX2, drawing /358
Selected heading (heading error)	Synchro in course indicator AA/AH
Course selector datum (course error)	Synchro in course indicator AA/AH
VOR or localizer deviation	21B/RV75, drawing /327 (ILS/VOR systems, Part 12, Chap.6)

60. A course datum synchro is provided in the course indicator, and is positioned by the COURSE selector knob. Deviation from the selected course, shown by the difference between the course arrow and the lubber line, produces an error signal from this synchro; this signal is fed to the steering computer for use in the ILS mode and to the bearing computation circuits of ILS/VOR systems (Part 12, Chap.6).

61. Lateral guidance information is supplied to the pilot by means of the steering pointer in the approach horizon indicator. The steering pointer is driven by the steering computer.

62. The heading error, course error, and VOR/LOC deviation inputs to the steering computer produce bank-demand signals that cause the steering pointer to move to left or right to indicate the bank required to fly the desired course. As the simulated aircraft is banked, the bank synchro signal cancels the bank-demand signal to give zero output to the steering pointer, which returns to centre.

63. Pitch trim is applied to the pitch bar through a differential gearing arrangement. In the ILS mode, the pitch servo (in the approach horizon indicator) automatically positions both the TRIM knob and the pitch bar to a preset position, as required for the approach attitude of the simulated aircraft. In the HDG mode, the pitch TRIM knob can be adjusted manually so that a pitch attitude, other than horizontal, may be used as a reference.

64. The Collins steering computer can be failed by the flight instructor by means of the IFS ATT 1 fail switch XF/AK/S8. Operation of this switch (normally-closed)

releases relay XX/CY/RL11 (and /RL12, para.47), and contact set /RL11/1 disconnects the 115V, 400c/s, supply from the steering computer. The coil of the STEERING flag, in the approach horizon indicator, de-energizes and allows the STEERING flag to become visible. Failure of the aircraft electrical supplies also causes the STEERING flag to appear; in this instance, contact set XX/CX/RL11/1 (coil of which is shown on /358), releases and disconnects the 115V, 400c/s, supply from the computer.

65. A GYRO flag appears in the approach horizon if a gyro failure is simulated or if the aircraft electrical supplies fail. The coil of the GYRO flag is controlled by contact set XX/CX/RL16/4; the coil of /RL16, shown on drawing /355, is energized with XX/CX/RL17, as described in para.35.

66. The starboard (co-pilot's) Collins IFS instruments are controlled and function in a similar manner to that of the pilot's instruments.

COLLINS/SPERRY SELECTION (/361)

67. When the indicators of the two flight systems are interchanged, some of the associated electrical signals must be disconnected from the system not in use and connected to the newly-selected system. This is achieved by relay-switching. The Collins/Sperry selection system consists of seven relays, controlled by the SPERRY and COLLINS push-buttons XF/AK/S11 and XF/AK/S12, respectively.

68. When the simulator is first switched on, the seven relays are released and lamp /S11/LP11, in the SPERRY push-button, is energized via released contact set XX/CY/RL9/1. Initially, therefore, the SPERRY system is selected automatically. To select the Collins flight system, the COLLINS push-button is pressed, energizing the coils of the selection relays, which then hold via operated contact set /RL9/1. The SPERRY lamp extinguishes and the COLLINS lamp, /S12/LP12, lights. The Sperry system can be reselected by operation of the SPERRY push-button, which releases the selection relays.

69. The selection relays are tabulated, together with the functions of their contact sets in Table 4.

TABLE 4

Collins/Sperry selection relays

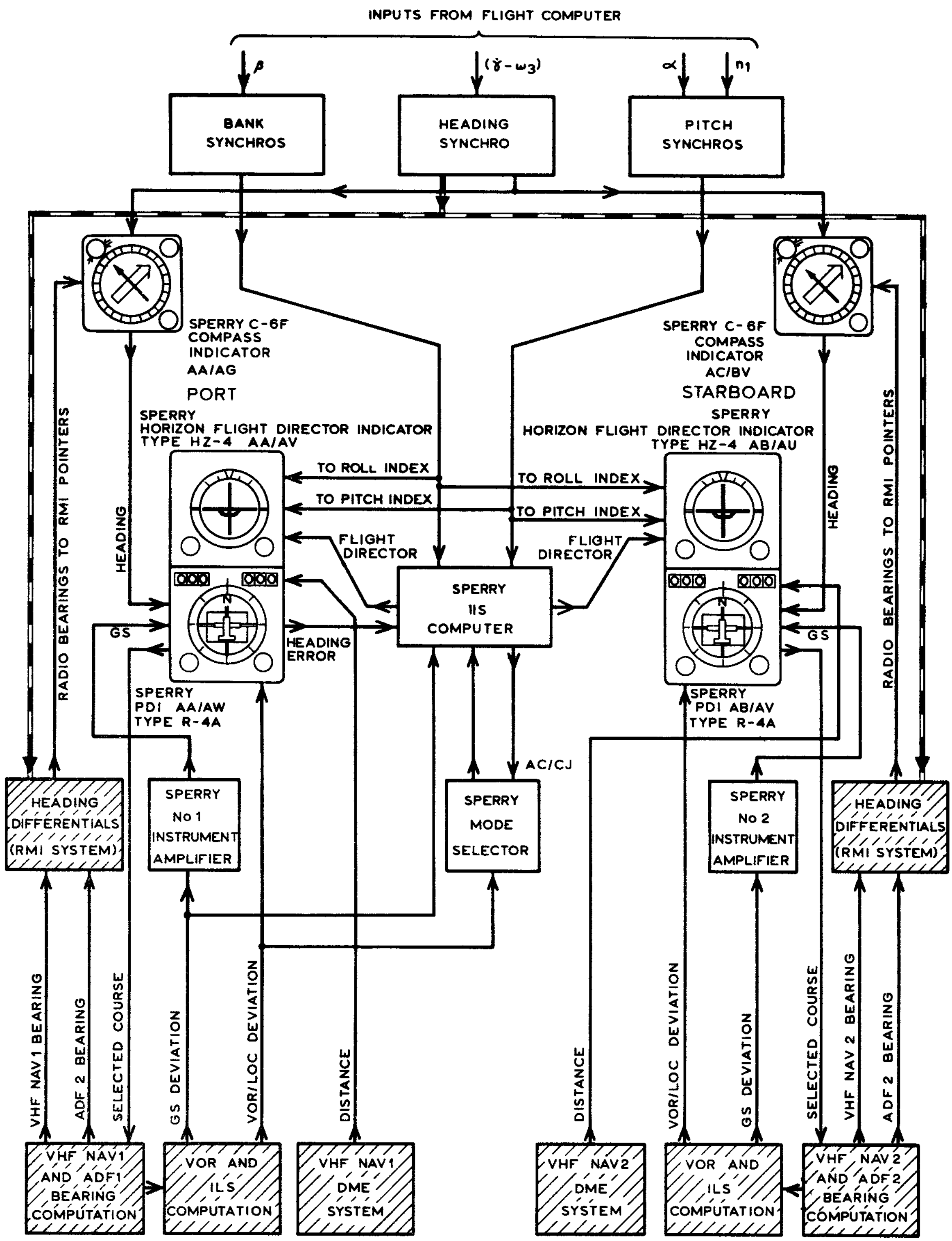
Relay:	Contact set:	Function:
21B/RL12	1	Routes VHF NAV 1 glidepath deviation signal to selected system (/327).
	2	Routes VHF NAV 2 glidepath deviation signal to selected system (/330).
XX/CY/RL6	1	Routes "units" signal from DME actuator synchro to the selected distance indicator (VHF NAV 1 DME, /335).
	2	As contact set No.1.
	3	As contact set No.1, but with respect to "tens".
	4	As contact set No.3.
XX/CY/RL7	1, 2, 3, 4	As relay XX/CY/RL6, but with respect to VHF NAV 2 DME, /336.
XX/CY/RL4 (Heavy-duty)	1, 2	Select "hundreds" synchros in the appropriate distance indicators of VHF NAV 1 DME.
XX/CY/RL5 (Heavy-duty)	1, 2	As relay XX/CY/RL4, but with respect to VHF NAV 2 DME.
XX/CY/RL8	1, 2	Selected course signal (para.60) fed, when receiver 3 tuned to VOR frequency, to resolver in VHF NAV 1 bearing computation, /326, (ILS/VOR systems, Part 12, Chap.6). Course signal obtained from Sperry PDI (/RL8 released) or from Collins course indicator (/RL8 operated).
	3, 4	As for contact sets 1 and 2, but with respect to VHF NAV 2 bearing computation, /329.

TABLE 4 (Cont'd.)

Collins/Sperry selection relays

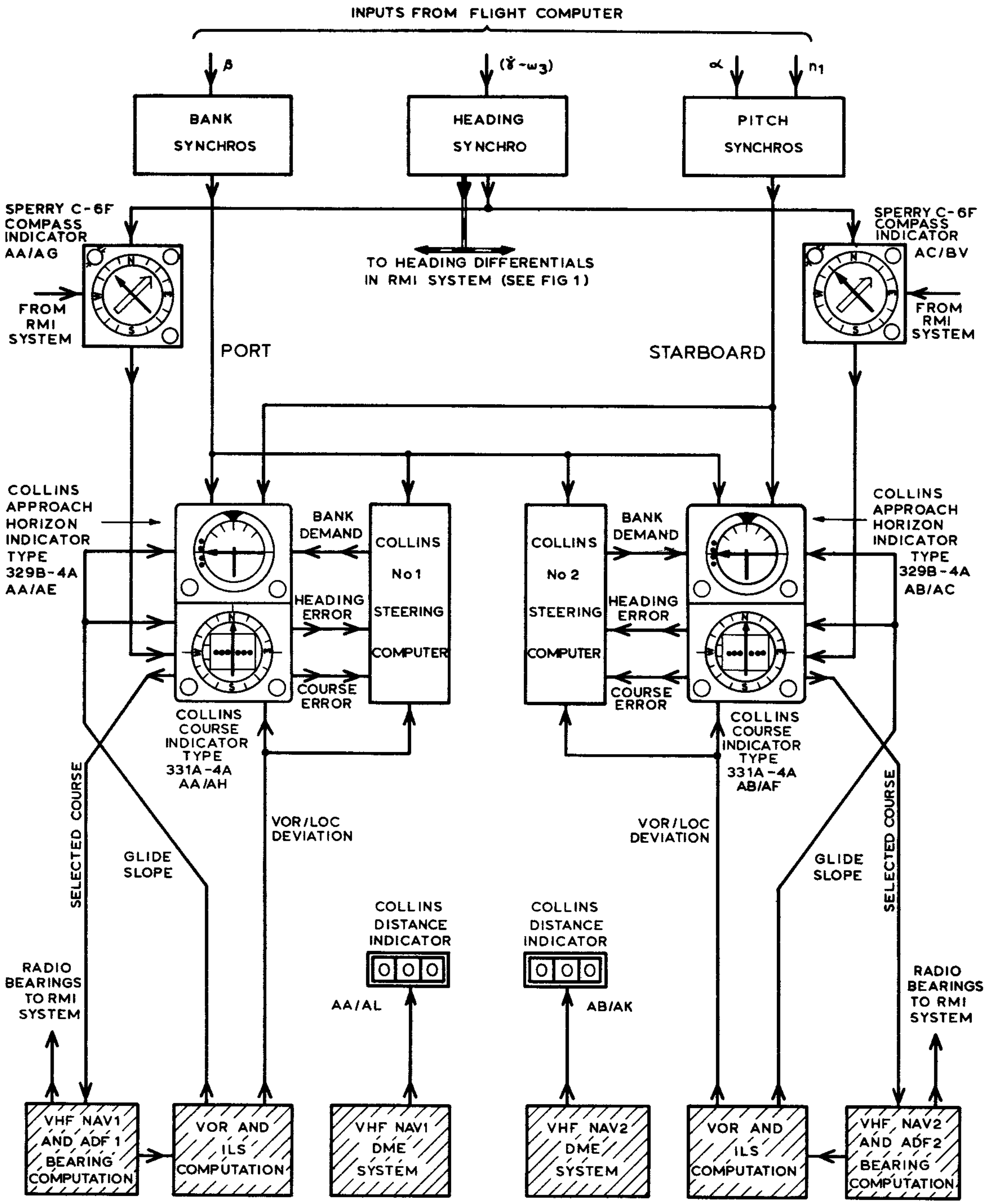
Relay:	Contact set:	Function:
XX/CY/RL9	1	Hold contact for selection relays (para 68).
	2	Operates obscuring shutter in Collins distance counter (fitted to pilot's instrument panel AA/AC) when Sperry selected (/335).
	3	Operates obscuring shutter in Collins distance counter (fitted to co-pilot's instrument panel AB/AK) when Sperry selected (/336).

Note...
All remaining components of the two flight systems are switched on permanently with the aircraft electrical supplies (subject to failures).



NOTE
ITEMS SHOWN CROSS-HATCHED ARE IN THE RADIO AIDS COMPUTER

Fig 1 Sperry IIS - block diagram



NOTE
ITEMS SHOWN CROSS-HATCHED ARE IN THE RADIO AIDS COMPUTER

Fig 2 Collins IFS - block diagram

Chapter 4

ROUGH AIR SYSTEM

List of Contents

List of Illustrations

General

1. The rough air system provides the flight computer with gust signals that provide simulated air turbulence effects. The system contains two pairs of series-connected gust units, No.1 and 2; the outputs of each pair of units is fed via the TURBULENCE control, which is located on the fuselage instructor's panel, and, via contact sets of the "gusts selected" relays to the flight computer loops and to the ADF circuit of audio system (Part 12, Chap.5).

ROUGH AIR SYSTEM CIRCUIT

2. The circuit of the rough air system comprises two identical pairs of gust units which, independently, produce air turbulence signals. The No.1 gust unit of each pair

contains two voltage regulators (that supply the necessary power to the gust units), and the basic gust signal generator. The No.2 gust unit shapes the basic signal into the turbulence signal. The gust units are not standard units, and are, therefore, described in this chapter.

Gust controls (/204)

3. The gust units are supplied with ±27V from the appropriate busbars in rack 13. The No.1 gust unit supplies ±20V regulated power for both gust circuits and the noise-signal input to the No.2 gust unit. The shaped signals from the No.2 gust unit are fed via capacitors 13D/T1/C1 and /C2 to the dual-ganged TURBULENCE control XF/AM/RV3a and b; this control is ganged to switch /S3, and operates when the switch control spindle is rotated from zero. Switch /S3 connects a supply that energizes the coils of the "gusts selected" relays 13D/T2/RL17 and /RL18. Simultaneously, the parallel connected lamp XF/AM/LP3, lights. The operated contact sets of these two relays connect the outputs from potentiometers/RV3a and b to the flight and radio aids computer systems.

4. The gusts 1 signal is fed to the roll, yaw and sideforce loops (Part 8, Chap.5), and to the lift loop (Part 8, Chap.3), via operated contact sets 13D/T2/RL17/3 and /4, respectively; the gusts 2 signal is supplied to the drag loop (Part 8, Chap.2), and to the lift loop (Part 8, Chap.3), via operated contact sets /RL18/3 and /4 respectively. The gusts 1 signal is also connected to the ADF shot-noise control circuit in the audio system (Part 12, Chap.5) from the junction of /C1 and /RV3a.

Gust No.1 unit (C218092/01)

5. The No.1 gust unit contains two voltage regulators, that provide ±20V, and an electronic noise generator.

±20V voltage regulators

6. The circuits of the +20V and -20V voltage regulators are basically similar and only the +20V regulator is described.

7. The output of the +20V stabilised power line is regulated by series transistor VT16. The base bias and current of VT16 is controlled by a voltage and current amplifier consisting of VT17, VT14 and VT15.

8. Transistors VT14 and VT17 are connected in a compound NPN and PNP pair. VT17 detects fluctuations and ripple on the +20V output: the amplified error

signal is applied to the base of VT15 which is connected in a Darlington circuit with VT16. Zener diode MR3 provides a constant-voltage base bias for VT14. A reference voltage is provided in the emitter circuit of VT17 by Zener diode MR6; the base of VT17 is connected via capacitor C14 and potentiometer RV3 to the +20V output and thus senses the a.c. and d.c. errors. The output line voltage can be varied by the setting of potentiometer RV3 which is, normally, preset for a +20V output.

9. The +28V line supplies various inductive loads, i.e., relay coils and motors. High reverse-potentials might, therefore, be fed into this regulator, and could destroy the transistors if these were reverse-biased; for this reason diodes MR4, 5 and 7 are connected between the base and emitter of VT15, 16 and 17, respectively, to prevent the base-emitter junctions from reverse-biasing, and thereby protecting the transistors.

10. The circuit of the -20V voltage regulator is similar to the circuit of the +20V regulator, but does not include diodes equivalent to transistor protection diodes MR4, MR5 and MR7 in the +20V circuit, because the -28V supply loading is mainly non-inductive.

Noise generator

11. A white-noise signal of approximately 50mV is generated by transistor VT1 which operates at an excessive forward base-bias, obtained from the junction of resistors R1 and R2. The noise signal appearing at the collector of VT1 is amplified by cascaded transistors VT2 and VT3, and is further amplified by direct-coupled stages comprising transistors VT4, VT5 and VT6, that are biased from the +20V regulated supply. The d.c. negative feedback loop (capacitor C7 and resistors R19 and R20) provides stabilization of the direct-coupled stages and limits the output at VT6 collector to -15V.

12. Subsequent stages (VT7, VT8 and VT9) include high- and low-pass filters that are designed to select a narrow band of frequencies, of between approximately 150 to 300c/s, from the wide range of the amplified white-noise spectrum. The two filters consisting of C8, R23 and C9 (high-pass), and C10, R28 and C11 (low-pass), are each preceded by a buffer transistor, VT7 and VT8 respectively.

13. The narrow band signal is fed to the base of output emitter-follower VT9; the output signal amplitude is preset by RV1 to approximately 0·8V peak-to-peak.

Gust No.2 unit (C218135/01)

14. The No.2 gust unit produces a constant-power spectrum, of very low frequency, by clipping the amplified white-noise signal obtained from the No.1 gust unit. The

inter-modulation products, resulting from the non-linear operation of the diode clipping circuit, contain a range of frequencies between 0 to 15c/s; this band of frequencies is then shaped and amplified to produce the required output of 0·1 to 3c/s at 8V peak-to-peak.

15. Transistors VT1 and VT2 amplify the low-frequency band of white noise from the No.1 gust unit to approximately 10·5V peak-to-peak. The amplified signal is fed to the emitters of VT3 and VT4 that act as clipping diodes operating at approximately 5·5V peak-to-peak. The clipping level is determined by Zener diode MR2 that is connected between the bases of VT3 and VT4; potentiometer RV1 is preset to obtain symmetrical clipping about 0V level.

16. The clipped low-frequency band of signals, consisting mainly of inter-modulation products of between 0 to 15c/s, is then amplified by low-drift differential amplifier, VT5 and VT6. The gain of this stage is preset by biasing potentiometer RV2, or by an external potentiometer that can be used when R14 is linked to PL1/AE. VT6 is fed with very low-frequency signals from the output of the unit (para.18), via a filter-network of R27, C8 and R23. The (relatively) large-capacity value of C8 (1000μF), becomes ineffective at frequencies below 0·1c/s and, consequently, the amplification of the difference signal is frequency selective and non-linear (x15 at d.c.). Capacitors C4, C5 and C6 prevent the high-frequency signals saturating the difference amplifier (VT5 and VT6).

17. The subsequent stages of the circuit, VT7 to VT11, inclusive, fulfil the functions of a low-pass filter and a d.c. amplifier. Direct coupling between stages preserves all the low-frequency components below 3c/s. Capacitors C7, C9, C10 and C11 and the associated resistors form the low-pass filters. Provision is made for connecting additional filter capacitors externally via pins PL1/R, /L, /J and /H, respectively. Surge-protection for buffer transistor VT8 is provided by diode MR3.

18. Losses incurred within the filter circuit are compensated for by the gain of the amplifier and output stage, formed by VT10 and VT11. Zener diodes MR4 and MR5 limit the maximum signal output of the unit to 8V peak-to-peak; the output signal amplitude can be varied by means of preset potentiometer RV3.

Chapter 5

WARNING SYSTEM

List of Contents

List of Illustrations

Introduction

1. The warning system provides the crew with visual indications of aircraft system failures, and of the presence of certain conditions where caution must be observed. The warning system consists of an annunciator warning panel (a.w.p.), fitted to the centre instrument panel, pilot's and co-pilot's master CAUTION lamps, and an ANNUNCIATOR TEST switch. The a.w.p. contains sixteen translucent legends that are engraved with the names of the relevant aircraft systems and which are illuminated when a fault or potentially dangerous condition arises in its associated system. Each legend is attached to a lamp module which occupies a specific position on the panel and which can be unplugged for servicing or for replacement of lamps. Each module contains three lamps to increase the reliability of the warning system. Only nine of the possible sixteen fault legends are used in the simulator.

2. Both the pilot's and co-pilot's master CAUTION lamps are lit when any one of the legends on the a.w.p. is illuminated. Each CAUTION lamp is integral with a reset switch and is similar in appearance to the engraved legends on the a.w.p. Operation of either reset switch causes both CAUTION lamps to be extinguished, but the legend on the a.w.p. remains illuminated until the fault is cleared. The CAUTION lamps are re-lit if, subsequent to their being reset, a further fault occurs.

3. The annunciator warning panel contains the following legends (given in the order in which they appear on the panel):

(1)	BRAKE PRESS LOW	-	(fault)
(2)	CABIN PRESS HIGH	-	(not used)
(3)	CABIN PRESS LOW	-	(not used)
(4)	CABIN DOOR UNLOCKED	-	(not used)
(5)	SPEED BRAKE EXTEND	-	(cautionary)
(6)	GENERATOR OUT	-	(fault)
(7)	NO.1 GEN OVERHEAT	-	(not used)
(8)	NO.2 GEN OVERHEAT	-	(not used)
(9)	NO.3 GEN OVERHEAT	-	(not used)
(10)	NO.4 GEN OVERHEAT	-	(not used)
(11)	INVERTER OUT	-	(fault)
(12)	FUEL PRESS LOW	-	(fault)
(13)	THRUST REV PRESS LOW	-	(fault)
(14)	OIL PRESS LOW	-	(fault)
(15)	ANTI SKID OUT	-	(cautionary)
(16)	STARTER ENGAGED	-	(cautionary).

The SPEED BRAKE EXTEND legend is illuminated continuously if the speed brake is in any position other than fully retracted when the landing gear is retracted; when the landing gear is also extended, the legend and the CAUTION lamps flash on and off regularly. In the latter instance, the CAUTION lamps cannot be reset unless the landing gear is retracted.

4. Some aircraft systems that contain a number of identical sub-systems are served by one common legend that is illuminated when a fault occurs in any one of the sub-systems. For example, if any one of the four engine-driven generators should fail, the GENERATOR OUT legend is illuminated. Operation of either reset switch causes the CAUTION lamps to be extinguished, but a failure of any one of the remaining three generators will re-light the CAUTION lamps. The GENERATOR OUT legend remains continuously illuminated until all generator faults are cleared. Other systems using a common legend for more than one fault are the fuel system (Part 7, Chap.2), containing six fuel tanks and served by the FUEL PRESS LOW legend, and the electrical system (Part 10, Chap.1), containing three inverters and served by the INVERTER OUT legend.

5. An ANNUNCIATOR TEST switch is provided. Operation of this switch away from its spring-biased centre-off position to the BRIGHT position causes all the annunciator warning panel legends, and the CAUTION lamps, to light at normal brilliance; all subsequent faults will then cause normal bright illumination of the respective legends. Setting the switch to DIM has no immediate effect, but any subsequent fault illuminates the appropriate legend, and lights the CAUTION lamps, at reduced brilliance. This dimming facility is not available, however, when the engine fuel control panel and centre stand lights are off.

WARNING SYSTEM (/011)

6. The operating circuit of the lamp module, typical of all the annunciator warning panel legends, is shown in Fig.1; component references shown on Fig.1 are for the purpose of description only.

7. A fault occurring in any of the systems indicated by the annunciator warning system causes the earth rail to be connected to the relevant lamp circuit (pin L of the typical circuit shown on Fig.1). The three lamps in the module light, being energized via pin L, diode MR2 and pin V (on the typical circuit), and via released contact set 14G/T26/RL17/2 and operated contact set /RL16/1 (on the system circuit). Simultaneously, the master CAUTION lamps AC/AC/LP1 and AC/BP/LP1 are energized via released contact set /RL17/1, their earth return being completed via diode /MR17, diode MR1 in the module, and released contact set RLA/1.

8. Operation of either CAUTION reset switch AC/AC/S1 (pilot) or AC/BP/S1 (co-pilot) energizes RLA via pin U and MR3, and RLA then holds via operated contact set RLA/2, pin W, and /RL16/1. Contact set RLA/1 operates and disconnects the earth return to CAUTION lamps, which extinguish. If a fault subsequently arises in any of the remaining systems, the relevant legend will be illuminated and pin T will be earthed via the contact set and diode equivalent to RLA/1 and MR1 in the typical circuit. The earth-potential at pin T causes the CAUTION lamps to light; these lamps can be reset again by operation of the CAUTION reset switches, as described.

9. The GENERATOR OUT, INVERTER OUT, and FUEL PRESS LOW warning legends are operated by a relay-and-diode OR-gate circuit that ensures that a fault in any generator, inverter, or fuel feed line causes the appropriate legend to be illuminated. For example, a fault in the No.1 generator connects the earth rail, via /MR43 and /MR59 to pin F of the annunciator warning panel to illuminate the GENERATOR OUT legend and to light the master CAUTION lamps. In addition, /RL3 is energized via /MR43 and released contact set /T27/RL14/2. Contact set /RL3/2 connects the CAUTION lamps to earth, thus duplicating the action of contact set RLA/1 in the typical circuit. If one of the CAUTION reset switches is operated, RLA de-energizes and /T26/RL19 is energized. Contact set /RL19/3 connects +27V to the coil of /RL14, via diode /MR30, and /RL14 energizes, its earth return being via the contacts of the fault relay in the No.1 generator circuit. Contact set /RL14/2 opens and disconnects the earth return from /RL3, which then de-energizes, releasing contact set /RL3/2 and extinguishing the CAUTION lamps. Relay /RL14 is self-holding, via contact set /RL14/1, and is only de-energized when the generator fault is cleared.

10. If a second fault occurs in one of the three remaining generators, /RL3 will be energized via diode /MR44, 45 or 46, and released contact sets /RL15/2, /RL16/2 or /RL17/2, and the CAUTION lamps light via operated contact set /RL3/2. Operation of the CAUTION switches energizes /RL19 and, consequently, the respective

"generator out" relay (/RL15, 16 or 17) energizes and holds via its own No.1 contact set, while the No.2 contact set breaks the energizing current for /RL3. Released contact set /RL3/2 then extinguishes the CAUTION lamps. The GENERATOR OUT legend remains illuminated until all generator faults have been cleared.

11. Operation of INVERTER OUT and FUEL PRESS LOW warning lamps is logically identical with that of the GENERATOR OUT warning described in para.9 and 10.

Annunciator test switch

12. The lamps in the a.w.p. and in the CAUTION switches can be dimmed or tested by use of the ANNUNCIATOR TEST switch AC/BJ. When this switch is set to DIM, relay /T26/RL17 is energized and holds, when the switch is released, via operated contact set /RL17/1.

13. Contact set /RL17/2 operates and disconnects the +27V supply from pin V of the annunciator warning panel. The lamp-energizing supply for each legend is therefore connected via a resistor (R1 in Fig.1) and the legends are illuminated, if a fault occurs, at reduced brilliance. In addition, operation of contact set /RL17/1 disconnects the direct supply connection from the CAUTION lamps, allowing them to be energized, if a fault occurs, via dimming resistors AC/AC/R1 and AC/BP/R1.

14. If the ANNUNCIATOR TEST switch is subsequently set to BRIGHT, /RL18 is energized, and /RL17 de-energized by contact set /RL18/1. The circuit is thus restored to its original condition and all subsequent fault lamps light at normal brilliance. While the switch is held in the BRIGHT position, all the lamps on the a.w.p., and those in the CAUTION switches, light at normal brilliance. Operation of the switch connects an earth to the lamps in all the modules, via pin S of the a.w.p. and diode MR4 in the typical circuit. This earth connection is continued via released contact set RLA/1, diode MR1, pin T, and /MR17 to the CAUTION lamps so that these also light. The master CAUTION reset switches can also be tested while the ANNUNCIATOR TEST switch is held in the BRIGHT position.

15. If the centre stand and engine fuel control panel lights are off (normally in daylight), +27V is connected, from the OFF position of dimmer switch RB/AG (cockpit lighting, Part 10, Chap.10) to the coil of /RL18. Operated contact set /RL18/1 prevents selection of /RL17 when the ANNUNCIATOR TEST switch is set to DIM, and the dimming action, described in para.12 and 13, cannot take place.

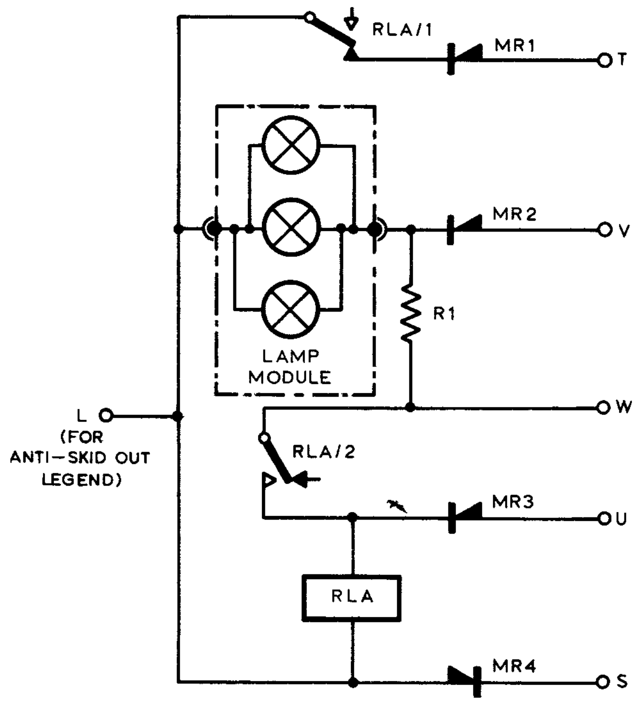


Fig 1 Typical circuit

PART 10

ANCILLARIES

Chapter 1

ELECTRICAL SYSTEM

List of Contents

List of Illustrations

General

1. The function of the electrical system is to simulate the aircraft power supplies and distribution. The simulated aircraft electrical installation includes the following systems:

(1) d.c. supplies
(2) a.c. supplies
(3) metering circuits.

The three systems are independent and are described in separate sections; a fourth section deals with miscellaneous electrical circuits.

D.C. GENERATION AND DISTRIBUTION

2. The aircraft d.c. electrical power is supplied by:

(1) four d.c. generators, fitted one to each engine
(2) two 24V batteries.

The d.c. supplies are fed to three independent d.c. busbars which consist of the following:

(1) main d.c. busbar
(2) essential d.c. busbar
(3) start and ignition busbar.

During normal operation, the aircraft batteries are connected in parallel to the essential d.c. busbar; the four d.c. generators supply the main busbar and, via the "busbar tie" circuit breaker (SL/53), the essential d.c. busbar and the aircraft batteries. The start busbar, through which the engine starting power is delivered, can be connected to the ground supplies, or to the aircraft batteries which are then effectively connected in series to provide the necessary high starting voltage. A safety circuit ensures that the aircraft batteries are disconnected from the busbars if the battery voltage is lower than 12V. During engine starting, the d.c. generators are utilized as starter motors; when the engine is lit, the respective generator reverts to its original function and supplements the start busbar supplies for starting the remaining engines. For emergency operation of those aircraft systems which are supplied from the essential busbar, one generator can be selected to feed the essential busbar via an emergency selector switch and via the start busbar.

3. The simulated electrical system fulfils all the functions of the aircraft electrical system; in addition, failure of any d.c. generator can be introduced by means of the instructor's generator failure switches.

Ground battery circuit (/002)

4. The ground battery supplies are simulated by a +27V supply which is connected, by the flight instructor's GROUND SUPPLY switch, XF/AK/S21, to the start busbar. This switch is set to the off position for engine start when using the aircraft battery (para.5); this switch then connects the energizing supply to the "battery doors closed" relay 13G/T1/RL9, via the SUPPLY DOORS switch XF/AL/S8 in the doors closed position. This is to conform to the engine starting procedure and operation of safety interlocks (Part 7, Chap.3) which require open battery doors for ground battery start and closed doors for aircraft battery start. When the engine is started by the use of the ground battery, relay /T1/RL9 is operated via diode /T6/MR37. Contact sets of relay /T1/RL9 operate in the engine starting system (Part 7, Chap.3). With switch XF/AK/S21 in the "ground supplies available" position, the start busbar is energized, via diode 13G/T6/MR59, and the main d.c. busbar is also energized via /T6/MR60; the essential busbar can obtain its energizing current from the main busbar via the operated "busbar tie circuit breaker intact" contact set /T5/RL10/2 (para.12) and diode /T6/MR13, if circuit breaker SL/53 is made (para.45). Engine starting with the ground supplies can be attempted; equally, any services which are supplied from the main and essential busbars can be switched on for testing purposes, etc.

Aircraft battery circuit (/002)

5. The two aircraft batteries are simulated by the "battery on" relay 13G/T1/RL7 which is energized when the +27V supply is connected via released contact set 13B/T1/RL5/4 (of the "crash relay" included in the drag loop, Part 8, Chap.2), released contact set /T3/RL1/1 (operated only if the battery voltage is reduced below 12V, para.38), diode /T6/MR17, and via the ON pole of the ON/OFF battery switch RD/AD mounted on the engine start panel. Operated contact set /T1/RL7/1 connects the energizing supply to the essential d.c. busbar and to the associated relays (para.42) Diode /T6/MR16 prevents the energizing of the essential d.c. busbar before relay /T1/RL7 is energized; the diode also provides an alternative path for the energizing current for relay /T1/RL7 from the essential busbar, when the motor-generators supply current to the main and essential busbars. In the absence of external battery supplies, the aircraft battery can be used for engine starting provided that the "battery series" relay /T1/RL15 (/003) is energized, and the start busbar is energized via operated contact set /T1/RL15/1 and diode /T6/MR15. Relay /RL15 can be operated only when the instructor's SUPPLY DOORS switch XF/AL/S8 is operated, thus energizing relay /T1/RL9 and, consequently, the "battery series control" relay /T1/RL16; the contact sets of these relays operate in the engine starting circuits (Part 7, Chap.3).

D.C. generator circuits (/002 and /003)

6. The circuits of the four engine-driven generators are similar and only the circuit of engine No.3 generator is described; the No.3 engine is, normally, selected first for engine starting (Part 7, Chap.3). The various stages of generator output switching are simulated by switch card 14DS/RV3 (/002), the wiper of which is energized with +27V supply from the "crash relay" contact set 13B/T1/RL5/4 (para.5) The four contact sections of the switch card provide the following functions:

(1) 0 to 15 per cent RPM section supplies the "low-fuel pressure warning" circuit of the fuel system (Part 7, Chap.2).
(2) 15 to 27·8 per cent section is not used.
(3) 27·8 to 43 per cent section supplies the "generated" current, via released contact set /T1/RL5/3 (main d.c. busbar not energized), to the charging circuits and to the main busbar (para.7); this condition simulates a generator output of approximately 18V.
(4) 43 to 110 per cent section supplies the full "generated" current directly to the charging circuits and to the main busbar.

7. When, during engine starting procedure the first engine (e.g., No.3 engine) is lit, and the engine speed exceeds an indicated 27·8% RPM (para.6(3)), the respective N switch card (14DS/RV3) begins to supply charging current to the main d.c. busbar via released contact set /T1/RL5/3 (main d.c. busbar not yet energized), operated contact set /T2/RL3/3 (No.3 generator field switched on, para.14), the ON pole of the EMER/OFF/ON No.3 generator control switch, RC/AL, and diode /T6/MR3. The "main d.c. busbar on" relay /T1/RL5 tends to become energized, but its energizing current is interrupted, for a short period, by operating contact set /T1/RL5/3, until the No.3 engine speed exceeds 43 per cent RPM and contact set /T1/RL5/3 is by-passed. With switch RC/AL set to ON, the "No.3 generator on" relay /T1/RL3 is energized and the corresponding GEN OUT lamp RC/AU (/003) is extinguished by the operated No.1 contact set of this relay (para.16), provided that the corresponding FLD TRIP/OFF/RESET switch (para.14 and 15) is set to the RESET position.

8. With the switch card wiper in the 43 to 110 per cent section (full generator output), the main d.c. busbar is energized and the relays which simulate the main busbar (para.42) are energized (/007), via interconnection (1). The essential busbar is energized via operated contact set /T5/RL10/2 and diode /T6/MR13. When starting the engines with the aircraft battery supplies, the start busbar supplies are supplemented from the essential busbar via operated contact sets /T1/RL7/1 and /T1/RL15/1, and diode /T6/MR15.

9. In an emergency, e.g., aircraft battery potential below 12V (contact set /T3/RL1/1 operated and, consequently, contact set /T1/RL7/1 released), the

output of any operating generator can be connected, via the EMER position of the generator control switch (RC/AL for No.3 generator), and via the respective GEN position of the EMER. GEN. SEL. SW., RM/AC, and diode /T6/MR18, to the start busbar. In this instance, the "busbar tie, generator transfer" relay /T1/RL8 is energized, and its contact set /T1/RL8/1 connects the essential busbar to the start busbar via diode /T6/MR14 and circuit breaker SL/54. Simultaneously, the start busbar supply is connected, via interconnection (13), to the "battery on charge" relay 13G/T3/RL2 (/005), the contact set of which operates in the d.c. voltmeter circuit (para.36).

10. The second set of contacts of the No.3 generator control switch RC/AL and of the other similar generator control switches are wired in parallel and provide, in the EMER position, energizing current from the "essential busbar supplies" contact set /T4/RL3/1 (/007), via the START circuit breaker PK/93 (interconnection (12), to the "start lock-out" relay /T1/RL10. The contact sets of this relay operate in the circuits of the engine starting system (/003 and /104, Part 7, Chap.3).

11. The second section of switch RM/AC supplies the selected "starter on" relay of the engine starting system (Part 7, Chap.3), via interconnections (15) to (18), and, via diodes /T6/MR9 to /MR12, the LOAD meter gauge (para.34) of the selected generator (interconnections (8) to (11)). The LOAD meters are also supplied from the charge lines of each generator via diodes /T6/MR5 to /MR8, via interconnections (4) to (7).

12. The BUS TIE RELAYS NORM faultable circuit breaker SL/53 (para.45) provides the normal connection between the main and essential d.c. busbars; this busbar tie connection is represented by operated contact set /T5/RL10/2. The aircraft battery (relay /T1/RL7) is, normally, charged (energized) from the essential d.c. busbar. The "aircraft battery" can be disconnected from the essential busbar by setting the battery switch RD/AD to OFF, thus de-energizing the coil of the "battery on" relay /T1/RL7. Operated contact set /T5/RL10/2 also energizes the coil of the "main d.c. busbar and fuse intact" relay /T1/RL6, the contact sets of which operate in the circuit of the "battery on charge" relay /T3/RL2 (contact set /T1/RL6/1, para.36), and in the a.c. busbar system (contact set /T1/RL6/2, para.29).

<u>Control circuit of No.1 d.c. generator</u> (/003)

13. The control circuits of the d.c. generators are similar, except for component references, and only circuit of No.1 generator is described.

14. Initially, the FLD TRIP/OFF/RESET generator field switch RC/AN must be operated to RESET to reconnect the generator field circuit. In this instance the +27V supply from the "essential busbar" contact set /T4/RL3/1 (/007) is routed via interconnection (2), GEN TRIP & RESET circuit breaker PK/96, diode RC/MR1,

RESET pole of switch RC/AN, FIRE 1 PULL handle switch AC/AM (fire warning system, Part 10, Chap.9), to the "generator field on" relay /T2/RL1 which is then held energized by operated contact set /T2/RL1/2 and released contact set /T1/RL17/2 of the "generator No.1 tripped" relay. Operated contact set /T2/RL1/3 connects the "generated" output of No.1 generator to the busbar circuits (para.7). Operated contact set /T2/RL1/4 connects the "generated" output of No.1 generator to the voltage measuring circuits (para.35). The +27V supply from switch AC/AM is also fed, via interconnection (4), to the "field reset" relay in the engine start circuits (Part 7, Chap.3)

15. When required, the No.1 generator output voltage can be reduced (to zero) by setting the FIELD switch RC/AN to the TRIP position thus energizing the "generator 1 tripped" relay /T1/RL17. The relay becomes self-holding via its operated contact set /T1/RL17/1 and released contact set /T2/RL1/1 of the "generator field on" relay /T2/RL1 which is de-energized by operated contact set /T1/RL17/2. The generator can be disconnected from the main d.c. busbar either manually by switch RC/AJ (/002) or, automatically, by released contact set /T2/RL1/3.

16. The operational state of the generator is indicated by the No.1 GEN OUT lamp RC/AS which also contains a press-to-test switch connected to the essential d.c. busbar contact set /T4/RL3/1 (/007), via the GEN OUT LT circuit breaker PK/97 and interconnection (2). When the generator is tripped and the No.1 generator control switch RC/AJ is set to ON (/002), contact set /T1/RL1/1 is released and the lamp lights.

17. Wired in parallel with lamp RC/AS is the control circuit of the GENERATOR OUT lamp, on the annunciator panel (warning system, Part 9, Chap.5); this lamp lights when its control circuit is earthed via interconnection (11) and released contact set /T1/RL1/1, or via an equivalent circuit of any other GEN OUT lamp.

18. Failure of the No.1 generator can be simulated by means of the flight instructor's fail/normal GEN 1 switch XF/AK/S29 which, in the fail position, supplies a +27V energizing voltage to relay /T1/RL17 (para.15). The No.1 GEN OUT lamp is also lit (para.16) due to the de-energized state of relay /T2/RL1 and /T1/RL1 which are released when contact set /T1/RL17/2 operates. If attempts are made to reset the generator field circuit, by the use of switch RC/AN, the lamp will extinguish whilst the switch is operated to the RESET position, provided that the EMER/OFF/ON generator control switch is set to ON and relay /T1/R1 operates (/002).

19. Drawing /003 includes additional essential controls of the engine starting system which are described in Part 7, Chap.3. These controls include the START switch RD/AF, the AIR START/OFF/NORMAL switch RD/AG and the GRD. START-off-BAT. START switch RD/AE; these switches control the engine starting circuits. The GRD. START-off-BAT. START switch provides selection of the starting power either from ground battery supplies or from the aircraft battery supplies (para.5).

A.C. GENERATION AND BUSBAR SYSTEMS

20. The aircraft a.c. electrical system is supplied by three 115V, 400c/s inverters which are energized from the main and essential d.c. busbars. The inverters are identified as No.1, No.2, and windshield inverter. The inverters feed eight a.c. busbars which are designated as follows:

(1) No.1 main a.c. busbar
(2) Windshield busbar
(3) Windshield emergency busbar
(4) Essential a.c. busbar
(5) No.2 main a.c. busbar
(6) Three instrument a.c. busbars which are not simulated separately.

Under normal operation, the No.1 inverter supplies the No.1 main a.c. busbar, the No.2 inverter feeds No.2 main a.c. busbar, and the windshield inverter supplies the windshield busbar. In an emergency, any one of the inverters can be selected to supply the windshield emergency and essential a.c. busbars.

21. The simulated a.c. electrical system performs all the functions of the aircraft system with only minor differences (para.20(6)). Failure of any of the three inverters can be introduced by means of the flight instructor's INVERTER failure switches.

115V, 400c/s inverter circuits (/004)

22. The three 115V, 400c/s inverters are independently controlled by the appropriate switches mounted on the a.c. control roof panel RE. The control circuit of No.1 inverter is fed with a d.c. supply from the simulated main d.c. busbar, represented by contact set /T4/RL7/1 (/007), via interconnection (14). When set to ON, the first section of the TRANSFER/OFF/ON NO.1 MAIN INV switch, RE/AJ, connects the +27V supply, via NO.1 MAIN CONT circuit breaker SJ/81 and the instructor's normal/fail MAIN INVERTER switch XF/AK/S26, to relay /T2/RL9 which represents, when energized, normal operation of the No.1 inverter. Operated contact set /T2/RL9/1 then connects the +27V supply from "main d.c. busbar" contact set /T4/RL7/1 (/007), via interconnection (6) and operated contact set /T2/RL13/1, to the No.1 main a.c. busbar, and to the essential a.c. busbar via released contact set /T2/RL18/1 (para.29). Energized relay /T2/RL13 represents the "main d.c. busbar and fuse intact" conditions which are achieved when the "main d.c. busbar fuse intact" contact set /T1/RL6/2 is made (para.12) and the "windshield emergency transfer" contact set /T2/RL17/1 is released (para.29).

23. The second section of switch RE/AJ is utilized during inverter transfer selection when the coil of "No.1 main transfer" relay /T2/RL10 is energized (para.30) via

circuit breaker PK/98. This circuit breaker also connects the essential d.c. busbar supplies to the "No.2 main inverter output" relay /T2/RL12 via the instructor's normal/fail STANDBY INVERTER switch XF/AK/S27, the OFF/ON NO.2 MAIN INV switch RE/AK and two released contact sets (/T2/RL10/1 and /T2/RL20/2) which are operated during inverter transfer selection (para.29 and 30). Operated contact set /T2/RL12/1 connects the energizing supply from switch RE/AK to the No.2 main a.c. busbar.

24. The windshield inverter circuit is similar to the circuits of the main inverters. The windshield busbar becomes energized when the WINDSHIELD INV switch RE/AH is set to ON, thus energizing the coil of the "windshield inverter output" relay /T2/RL19; operated contact set /T2/RL19/1 then connects the energizing supply to the windshield busbar via released contact set /T2/RL18/2 of the "windshield/No.1 transfer" relay (para.29). The windshield busbar supply energizes the coil of the "windshield inverter warning" relay /T2/RL14 (para.27) via released contact set /T2/RL17/2 of the "windshield emergency transfer" relay (para.29).

25. Any of the three inverters can be failed by the instructor's normal/fail inverter switches (XF/AK/S26 for No.1 inverter) which, in the fail position, disconnect the energizing supply from the respective "inverter output" relay; thus the respective busbars are de-energized unless emergency transfer is selected (para.26).

Emergency inverter selection

26. Under emergency conditions (e.g., failure of an inverter), any inverter can be selected to supply the windshield emergency busbar and the essential a.c. busbar. The state of the three main a.c. busbars is indicated by three warning lamps, on panel RE, which light when a busbar supply is failed and the respective busbar is de-energized.

27. The three BUS OUT warning lamps RE/AE, /AL and /AM are supplied with +27V via operated contact set /T21/RL19/2 (representing, when operated, the "essential d.c. busbar on"); the lamp circuits are completed via three individual contact sets /T2/RL14/1, /T2/RL15/1 and /T2/RL16/1 when these are released. The coils of relays /RL15 and /RL16 are normally energized by contact sets representing the essential a.c. and No.2 main a.c. busbars (para.42). Under normal conditions, relay /RL14 is operated from the windshield busbar supplies (para.24); when the windshield emergency busbar is energized (para.29), operated contact set /T2/RL17/2 connects the emergency busbar supplies to the relay coil.

28. Each of the warning lamps, RE/AE, /AL and /AM, is provided with the PRESS-TO-TEST facility which ensures, when used, that the essential d.c. supplies are on (contact set /T21/RL19/2 operated) and circuit breaker PK/95 is made. The warning

indication is repeated by the INVERTER OUT lamp, on the annunciator panel (warning system, Part 9, Chap.5); the control circuit of this lamp is connected, via interconnections (11), (12) and (13) respectively, to the circuits of the warning lamps on panel RE.

29. When a visual warning is given that one of the normal a.c. busbar supplies has failed, the appropriate emergency selection must be made. In the instance of failure of power from the windshield inverter (relay /T2/RL19 released), contact set /T2/RL14/1 releases and the WINDSHIELD BUS OUT warning lamp RE/AE lights. The WINDSHIELD INV switch RE/AH must be set to the TRANSFER position, and provided that the NO.1 MAIN INV switch RE/AJ is ON, the "No.1/windshield transfer" relay /T2/RL20 is operated, via released contact set /T2/RL10/2. Under these conditions, the No.1 inverter output from operated contact set /T2/RL9/1 is supplied, via released contact set /T2/RL18/1, to the essential a.c. busbar. The power required for the windshield heaters is then obtained from the windshield emergency busbar by selecting the windshield antice power control switch AB/AM to the EMER PWR position, thus energizing the coil of the "windshield emergency transfer" relay /T2/RL17 which then remains energized irrespective of subsequent re-setting of the AC SYS switch RE/AG. The No.1 main a.c. busbar is de-energized (by released contact set /T2/RL13/1) and the windshield emergency busbar is energized via released contact set /T2/RL13/2. The WINDSHIELD BUS OUT warning lamp RE/AE is extinguished (relay /T2/RL14 energized by operated contact set /T2/RL17/2), and the "No.1 main busbar disconnect" relay /T2/RL13 is de-energized by operated contact set /T2/RL17/1; contact set /T1/RL6/2 is normally operated, thus simulating the connection between the main and essential d.c. busbars. The second section of switch RE/AG energizes, when in the EMER position, the coil of the "windshield/No.1 transfer" relay /T2/RL18, the contact sets of which provide the routeing of the emergency supplies (para.30).

30. If, for instance, the No.1 inverter output is also failed, the NO.1 MAIN INV switch RE/AJ must be set to the TRANSFER position (relay /T2/RL10 operated and relay /T2/RL9 released), and the windshield emergency and the essential a.c. busbars are energized with No.2 inverter output via the following contact sets: /T2/RL18/1 (operated), /T2/RL18/2 (operated), /T2/RL19/1 (released), /T2/RL20/1 (operated) and /T2/RL12/1 (released).

31. When the windshield inverter is selected to provide the emergency power for the windshield emergency busbar and for the essential a.c. busbar, the AC SYS switch RE/AG is set to the EMER position, thus energizing the coil of the "windshield/No.1 transfer" relay /T2/RL18. The windshield inverter output is routed via operated contact sets /T2/RL19/1, /T2/RL18/2 and /T2/RL18/1 to the emergency busbars.

METERING CIRCUITS

D.C. instruments (/005)

32. The d.c. instruments of the electrical system comprise four LOAD meters, one for each generator, and a DC VOLTMETER; the instruments are mounted on the overhead d.c. control panel RC. The LOAD meters measure the output current of their respective generators. The DC VOLTMETER measures the output voltage of a selected generator or of the aircraft battery. Provision is made for introduction of faulty indication of any of the five instruments by the instructor's controls on panels XF/AL and XF/AK.

Load-meter circuit

33. The total d.c. current drawn from the d.c. busbar system is given by the effective resistance of parallel chains of resistors in the emitter circuit of transistor /T25/TR1; the generator outputs are individually connected in parallel in the collector circuit. The emitter resistors provide current scaling equal to:

$$\text{Current drawn (ampères)} = \frac{10\,350}{R}$$

where R is in kilohms.

The collector current of the transistor is, therefore, determined by the emitter loads only. This current is divided through the number of ammeters in the collector circuit and thus true load-sharing is achieved. The various load resistors are switched into the emitter circuit by contact sets of relays which represent certain aircraft services being used, e.g., operated contact set 14G/T3/RL1/3 represents the use of auxiliary hydraulic pump. The services are detailed on drawing /005 and their use and switching arrangements are self-explanatory.

34. The four LOAD meters (RC/AE, /AF, /AG and /AH) are connected to the respective generator outputs via the ON position of the respective generator control switch (para.11), or, if a generator emergency selection is made, via the corresponding position of the EMER. GEN. SEL. SW., RA/AC. Each LOAD meter is fed via the instructor's DECREASE/NORMAL/INCREASE potnetiometers (e.g., AMPS potentiometer XF/AK/RV5 for No.1 generator) by which increased or decreased reading can be introduced to simulate a load variation of the selected meter/s. The remaining ammeters share the corresponding load increase or decrease.

D.C. voltmeter circuit

35. The circuit of the D.C. VOLTMETER, RC/AC, consists of VOLTMETER SELECTOR switch RC/AD which connects one of five sources (battery, and 1 to 4 generators), via DH type amplifier 13FC/a, to the common voltmeter RC/AC. The output of No.1 generator is represented by a shaped potentiometer, 14BS/RV4, which is fed from the instructor's GEN 1 VOLTS potentiometer XF/AK/RV4. The output circuits of the other generators are similar. As soon as the generator field is switched on, contact set 13G/T2/RL1/4 operates and connects, if selected, a voltage proportional to the No.1 generator output to the voltmeter drive amplifier 13FC/a; when the engine speed N reaches 43.3 per cent, full generator output is obtained and maintained up to the maximum engine revolutions. Potentiometer XF/AK/RV4 enables the instructor to vary the generator output from 0V to 32V, thus simulating generator output faults.

36. The "aircraft battery" output circuit is normally supplied (when being charged via the essential busbar) from the +50V signal supplies via resistor 13G/T24/R4 which is connected via operated contact sets 13G/T3/RL2/1 and /T1/RL7/2 to the meter drive amplifier. Contact set /T1/RL7/2 is operated when the battery is switched on (para.5); contact set /T3/RL2/1 operates when relay /T3/RL2 (battery on charge) is energized from the main busbar (contact set 13G/T1/RL6/1 operated, para.12), or from the start busbar via diode 13G/T6/MR20 (para.9). If either of the two contact sets (/T3/RL2/1 or /T1/RL7/2) is released, the battery output voltage signal is proportional to the wiper setting of the BATTERY potentiometer XF/AK/RV1 with which the instructor can simulate battery voltages from 0V to 24V.

37. When the aircraft battery is used for engine starting, the battery voltage drop is simulated by the charging action of capacitor 13G/T24/C1 which is connected, by operated contact set /T1/RL15/2 (when the START switch is operated), to resistor /T24/R2. The battery voltage drops initially to 14V and then it increases to full value with a time constant of approximately 5 seconds. Resistor /T24/R9 discharges the capacitor when contact set /T1/RL15/2 is released.

38. When the battery voltage from potentiometer XF/AK/RV1 is reduced to half of its normal value (12V), the circuit of transistor 13G/T24/TR1 operates, and the "battery voltage less than 12V" relay /T3/RL1 is energized. The transistor is normally biased-off by the positive voltage from the wiper of potentiometer XF/AK/RV1; if this voltage exceeds +27V, diode /T24/MR1 conducts and short-circuits the transistor base to the emitter. When the potentiometer wiper voltage is between +27V and earth potential, the diode is non-conducting and the transistor conducts. Relay /T3/RL1 thus operates at a simulated battery voltage of +12V or less. Contact set /T3/RL1/1 operates in the start busbar circuit (para.5) where it disconnects the aircraft battery if its voltage is less than 12V.

A.C. instruments (/006)

39. The a.c. instruments comprise the AC VOLTS meter and FREQ METER on the overhead a.c. control panel RE. Each circuit consists of a meter, selector switch and source supplies which are switched on by contact sets representing the respective energized a.c. busbars.

40. The AC VOLTS meter, RE/AC, is connected via the BUS SELECT switch, RE/AF, either directly to the 115V a.c. supplies, when selected to 115V, or to voltage-dropping resistors (/T24/R21 for No.1 main a.c. busbar supplies) when selected to the 26V position. The "a.c. on" relays /T3/RL3, /RL4 and /RL5 are energized by the contact sets (/007) representing the energized a.c. busbars (para.42).

41. The FREQ METER, RE/AD, is connected, via the second section of the BUS SELECT switch RE/AF, to three +27V d.c. supplies which represent the 115V, 400c/s, supply. The meter circuit includes voltage dropping resistors /T24/R25 and /R26, and capacitor /T24/C2 which "slugs" the meter response thus giving an effective, slow-speed, inverter output variation. The simulated 400c/s supplies are taken from the instructor's FREQUENCY potnetiometers (XF/AL/RV3 for No.1 main a.c. busbar supply) which enable the instructor to vary the indicated frequency from 350 to 450c/s. Contact set /T3/RL3/2 connects the frequency measuring circuit to the +27V supply when the No.1 main a.c. busbar is energized.

BUSBAR DISTRIBUTION (/007)

42. When the simulated a.c. and d.c. aircraft busbars are energized, the required voltages (+27V, -27V and 0V) are connected, via operated contact sets of the "busbar live" relays, to the corresponding aircraft systems. The coils of the "busbar live" relays are connected directly, via diodes, to the simulated busbars which include three d.c. busbars and five a.c. busbars. Six busbar indicator lamps on the state panel 13BS are lit when the respective busbars are energized.

43. The circuit of the ELECTRICS TEST switch 13BS/S5 provides a common independent supply of +27V to all the "busbar live" relays and lamps, when the switch is operated to the test position. In this instance, all the busbar contact sets are operated, and the dependent services and systems can be tested for correct operation without the necessity of engine starting and generator or inverter operating.

FAULTABLE CIRCUIT BREAKERS (/008)

44. The instructor is provided with 12 normal/fail switches by means of which any of 12 selected circuit breakers can be failed. The switches and the corresponding

circuit breakers are identified on drawing /008; the circuits are similar and the operation of circuit breaker SL/53 is described.

45. Circuit breaker SL/53 provides the earth connection for the normally-operated "busbar tie circuit breaker intact" relay 13G/T5/RL10, the No.2 contact set of which operates in the d.c. generator circuit (para.12). The earth connection is made via one half of the centre-tapped secondary winding of the rack heater transformer (or rack 14); this 6·3V heater supply is tied to the earth potential (via the centre tap).

46. When the instructor's normal/fail NORMAL BUS TIE switch XF/AK/S13 is set to the fail position, relay 14G/T1/RL1 is energized, via SL/53. Operated contact set /RL1/1 connects the 6·3V heater supply across the circuit breaker which trips. All the faultable circuit breakers are rated at 2·5A, although the amperage rating inscribed on the circuit breakers' caps may vary from 0·5 to 50A. The heater supply line includes an isolating diode which is rated at 10A thus limiting the maximum number of tripped circuit breakers to four. Circuit breaker SL/53 remains open-circuited even if attempts are made to reset it, for as long as switch XF/AK/S13 is set to fail. Released contact set /T5/RL10/1 supplies +27V to switch lamp XF/AK/LP13 which lights, or extinguishes if attempts are made to reset the circuit breaker.

Chapter 2

HYDRAULIC SYSTEM

List of Contents

List of Tables

List of Illustrations

Introduction

1. The simulated aircraft hydraulic system comprises two independent systems: No. 1 (normal) and No. 2 (stand-by), the nominal maximum delivery pressure of either system being 3000 lb/in^2. The No. 1 system is normally powered by a pump driven by No. 2 engine, and the No. 2 system is powered by a pump driven by No. 3 engine. The hydraulic pressure is a function of engine speed within the range of 0 to 43·3 per cent (indicated) RPM; at engine speeds in excess of the ground idling speed (43·3 per cent), the hydraulic pressure remains constant at 3000 lb/in^2.

The aircraft No.1 hydraulic system is also backed-up by an electrically-operated (d.c.) auxiliary pump that can be switched on in the cockpit and which is energized automatically during landing gear retractions or trailing edge flaps extensions. The electrically-operated auxiliary pump is fully simulated and is controlled by the AUX HYD SYS 3 switch AC/BR.

2. In the event of insufficient pressure from the No.1 hydraulic system, i.e., No.2 engine speed below idling RPM. (para.13), or hydraulic shut-off valve operated (para.15), the pressure can be restored, by selection of the auxiliary pump, to 3000 lb/in^2 in approximately 30 seconds. The simulated hydraulic systems can be failed independently by the flight instructor; introduced failure of the No.1 hydraulic system fails also the auxiliary pump, and the No.2 system must be selected to power the respective simulated aircraft services. If, subsequently, the No.2 system is failed, a small reserve of hydraulic power is retained in the pressure-accumulators (para.3) for a short period.

3. The simulated aircraft services, supplied by the respective hydraulic systems, are listed in Table 1, and shown in Fig.1.

TABLE 1

Hydraulic power distribution

No.1 system:	No.2 system:
Aileron boost	Aileron boost
Elevator boost	Elevator boost
Landing gear	Flaps
Flaps	Wheel brakes (without anti-skid)
Wheel brakes (with anti-skid)	
Nosewheel steering	
Thrust reverser mechanism	
Airbrake	

The aircraft hydraulic systems are provided with pressure-accumulators to reduce pressure fluctuations due to the variations in pump speed. The pressure-accumulators are represented, in the simulator systems, by capacitors which are charged to a potential proportional to the operating pressure. In the event of a system failure, the particular accumulator-capacitor will become exhausted in approximately 100 seconds, this time being reduced almost to zero if the failed system is required to provide power to one of the hydraulically-operated services.

4. The simulated aircraft services, which are powered from the No. 1 system, remain operable down to a pressure limit of 1500 lb/in^2 (at 11 per cent RPM); below this limit, the pressure is insufficient to actuate these services. The No. 2 system has a small degree of hysteresis in its low pressure characteristic so that, although services powered by the No. 2 system function initially only when the pressure exceeds 1500 lb/in^2, they remain operable down to a limit of 1250 lb/in^2.

5. Hydraulic pressure of both systems is displayed on the HYD PRESS (hydraulic pressure) indicator, AC/BH, on the centre main instrument panel This instrument contains two pointers, one for each system. No warning of low pressure is given other than by the hydraulic pressure indicator.

6. The complete hydraulic system is simulated electrically; the upper and lower pressure limits are detected by discriminator circuits. The variable input voltages (that represent hydraulic pressure) are derived from N_2- and N_3-fed potentiometers as shaped functions. The discharge-rates of the accumulator-capacitors depend upon the different values of relay-selected resistors. The hydraulic pressure indicator pointers are driven by servo-motors controlled by positional loops that are fed from the same signal source as the discriminator circuits.

7. Hydraulic service demands from the No. 1 and No. 2 hydraulic systems are fulfilled according to two basic operational conditions. Condition 1 deals with demands made, and fulfilled, during normal system operation; condition 2 deals with demands made during certain conditions of system failure and subsequent depletion of No. 1, or No. 2, system and accumulator pressures. These two conditions are similar for both No. 1 and No. 2 systems and only the No. 1 system is dealt with; condition 1 (normal pressure demands) is described in para. 8 to 20, inclusive, and condition 2 (pressure loss) is described in para. 21 to 25, inclusive. The differences between No. 1 and No. 2 systems operation is described in para. 26 to 36, inclusive.

NO. 1 HYDRAULIC SYSTEM (/015)

Normal-pressure demands

8. Two discriminators are used in the simulated No. 1 hydraulic system; one senses hydraulic pressure greater than 1500 lb/in^2 and the other senses hydraulic pressure equal to 3000 lb/in^2. Each discriminator consists of a type DH amplifier, with feedback-limiting diodes connected from the output of the amplifier to the input summing junction. Also connected to the summing junctions of each amplifier is a -50V reference supply and a positive voltage representing the engine-driven pump pressure and the auxiliary, electrically-operated pump pressure. Diodes 13F/T7/MR4 and /MR6 limit the gain of amplifiers 13FE/a and /b, respectively, to zero when the input voltage is negative.

When the sum of the input and reference voltages becomes positive, at a level determined by the ratio of the summing resistors, /MR4 and /MR6 are reverse-biased and the respective amplifier gain is increased. The amplifier output negative voltage increases proportionally, and the associated relay coil energizes. Saturation of each amplifier is prevented by feeding back to its input a proportion of its output voltage, obtained from a potential-divider, via diodes 13F/T7/MR3 (amplifier 13FE/a) and 13F/T7/MR5 (amplifier 13FE/b), that limit the output of each amplifier to -90V, thereby safeguarding relay coils 14G/T3/RL8 and /RL9, respectively.

9. Indication of No.1 hydraulic system pressure is provided by pointer 1 of the twin-pointer instrument, AC/BH. This pointer is actuated by a servo-motor, which is controlled by a type DH amplifier, 13FD/a, and powered by an instrument drive amplifier, 13F/T5/a. Indication of normal hydraulic pressure, 3000 lb/in^2, is given by this pointer when the voltage at the junction of summing resistors 13F/T7/R2, /R3 and diode /MR2 is approximately +48V. Potentiometer AC/BH/RV1 supplies the positional signal, via /R3, for the servo loop.

10. The voltage representing the pressure of the No.1 hydraulic system No.2 engine-driven pump is obtained from the wiper of N_2 potentiometer, 14CS/RV5. The voltage from the wiper of /RV5 is a shaped function, f_5N_2. At 11 per cent of maximum RPM, $f_5N_2 = 0{\cdot}5$, corresponding to half-normal pressure, 1500 lb/in^2. At 43·3 per cent RPM, $f_5N_2 = 1{\cdot}0$, which corresponds to full pressure, 3000 lb/in^2; the function (input signal) remains constant at this value for all further increase of engine speed. If the No.2 engine is shut-off during airborne conditions, the indicated RPM will reduce to 11 per cent. Services powered by the No.1 hydraulic system thus remain operable. This situation simulates the availability of hydraulic pressure from the No.1 hydraulic system pump when the No.2 engine is windmilling.

11. Capacitor 13F/T7/C2 represents the pressure accumulator fitted to the No.1 hydraulic system; the capacitor is charged to the potential obtained from the N_2 potentiometer, via released contact sets 14G/T3/RL5/2 and /RL2/2, and resistor 13F/T7/R9. The voltage on /C2 is connected to the discriminators and the instrument servo-amplifier, 13FD/a, via resistor 13F/T7/R15 and diode /MR2. When the potential on /C2 reaches approximately +25V, the 1500 lb/in^2 discriminator (amplifier 13FE/a) energizes relay 14G/T3/RL8; the coil of "hydraulics available >1500 lb/in^2 "relay 13F/T3/RL12 is energized via contact set 14G/T3/RL8/1, and the HYD 1 lamp, 13BS/LP16 on the state panel, is lit. In addition, the +27V supply from operated contact set 14G/T3/RL8/1 is fed, via interconnection (15) to the flying controls and control loading system (Part 9, Chap.1) to simulate the availability of hydraulic pressure to the aileron and elevator boost circuits. When the potential on /C2 has increased to approximately +48V, the 3000 lb/in^2 discriminator energizes relay 14G/T3/RL9 and the pressure indication, on gauge AC/BH, increases to 3000 lb/in^2.

12. The output of the electrically-operated auxiliary pump (No.3 hydraulic system) is represented by the voltage at the emitter of transistor 13F/T7/TR1. This voltage, which is dependent on the charge on capacitor /C1, is fed, via diode /MR1, to the two pressure discriminators and to the input of the No.1 hydraulic system pressure indicator servo-drive amplifier 13FD/a. The voltage, representing the hydraulic pressure, applied to the discriminator and servo-drive amplifier summing resistors, is equal to the greater of the two voltages from the simulated engine-driven pump (13F/T7/MR2) and auxiliary pump (13F/T7/MR1). Operation of the auxiliary pump has, therefore, no effect on indicated pressure when the No.1 system is functioning normally, i.e., while the simulated engine-driven pump is maintaining full output.

13. If the No.2 engine speed is reduced to zero (during groundborne conditions), the voltage at the wiper of N_2 potentiometer 14C/RV5 becomes zero, and capacitor 13F/T7/C2 discharges rapidly via /R9 and released contact sets 14G/T3/RL2/2 and /RL5/2. The No.1 hydraulic system pressure can be restored by operation of the auxiliary pump. The simulated auxiliary pump is controlled by the AUX HYD SYS 3 switch, AC/BR. When this switch is in the ON position, "aux. hyd. pump on" relay 14G/T3/RL1 is energized from the essential d.c. busbar via circuit breaker SG/113; (automatic selection of the auxiliary pump is described in para.20). Capacitor 13F/T7/C1 begins to charge to +50V via released contact set 14G/T3/RL5/1, resistor 13F/T7/R4, and operated contact set 14G/T3/RL1/1. In approximately 30 seconds, the potential on C1 and that on the emitter of /TR1, rises to +48V; the No.1 hydraulic system pressure indicator then registers 3000 lb/in^2, and the 3000 lb/in^2 discriminator output energizes relay 14G/T3/RL9.

14. The No.1 hydraulic system can be failed by the HYD 1 fail switch XF/AC/S2 on the flight instructor's panel; operation of this switch causes "No.1 hyd. sys. fail" relay coil 14G/T3/RL5 to be energized. Operated contact set /RL5/2 discharges the No.1 system accumulator capacitor /C2, via released contact set 14G/T3/RL2/2, and one of the resistors 13F/T7/R10, /R12, /R13 or /R14. Normally, i.e., with the auxiliary pump switched-off and with no heavy demands on hydraulic pressure, capacitor /C2 discharges via resistor 13F/T7/R13, and the pressure indication reduces to zero in approximately 100 seconds. Setting the HYD 1 fail switch to the fail position also prevents operation of the auxiliary pump; contact set 14G/T3/RL5/1 is operated and disconnects the +50V supply to the circuit of /C1 and /TR1; subsequent selection of the auxiliary pump has no effect on the No.1 system hydraulic pressure.

15. If fire or overheating is detected in an engine compartment, the respective FIRE WARNING handles must be operated (fire warning system, Part 9, Chap.9). Each of the four FIRE WARNING handles actuates microswitches, the contacts of which affect relays in the simulated fuel system. Additional microswitch contacts are actuated by FIRE 2 PULL and FIRE 3 PULL handles to represent the operation of hydraulic fluid shut-off valves. If the FIRE 2 PULL handle, on the FIRE WARNING panel AC/AL, is pulled, the fuel to the No.2 engine is cut-off, thereby extinguishing the engine. The

No.1 hydraulic system pressure is reduced to zero. "Windmilling pressure" is not available, due to simulated operation of the shut-off valves. The No.1 system hydraulic pressure can be restored by switching on the auxiliary pump by means of the AUX HYD SYS 3 switch. This action also causes the No.1 system accumulator to be charged as soon as the pressure reaches 3000 lb/in^2, provided that no heavy demands are made upon the system.

16. When the FIRE 2 PULL handle AC/AN is operated, the coil of relay 14G/T3/RL2 is energized from the essential d.c. +27V busbar (interconnection (3)), via operated contact set 13G/T5/RL12/2. Relay /RL12 is controlled by a faultable circuit breaker switch (electrical system, Chap.1) and is, therefore, normally in the energized state. Relay /RL2 is provided with a holding circuit via operated contact set /RL2/4, from the +27V supply; if /RL12 is de-energized by the faultable circuit breaker after the FIRE 2 PULL handle is operated, then /RL2 remains energized. Contact set /RL2/3 provides an equalizing voltage across the coil of /RL2 when the FIRE 2 PULL handle is restored to its normal position, thus de-energizing /RL2. This equalizing voltage is not available if /RL12 is released, and /RL2, therefore, remains held-on via contact set /RL2/4.

17. The +27V from the essential d.c. busbar is connected via operated contact set /RL12/2, operated FIRE 2 PULL handle switch and interconnection (13) to the engine starting system (Part 7, Chap.3) to energize a relay which prevents No.2 engine starting while the FIRE 2 PULL handle is in the operated position. In addition, a second section of the FIRE 2 PULL handle switch energizes a relay which simulates the engine No.2 fuel shut-off valve (fuel system, Part 7, Chap.2).

18. Contact set /RL2/2 ("No.2 fire handle selected" relay), when operated as described in para.16, disconnects the No.1 hydraulic system accumulator, represented by capacitor /C2, from the wiper of the N_2-fed potentiometer 14C/RV5 thus simulating loss of pressure due to hydraulic fluid shut-off. Capacitor /C2 discharges via /R9, operated contact set /RL2/2, released contact sets /RL6/3, /RL10/2, /RL1/2, and resistor /R13. The indicated pressure reduces to zero in approximately 100 seconds, as in the instance of hydraulic failure effected by means of the instructor's fail switch (para.14). The simulated auxiliary pump, however, remains operable under these conditions; the No.1 hydraulic system pressure can, therefore, be restored by selecting the auxiliary pump (para.13).

19. When the 3000 lb/in^2 discriminator output energizes relay 14G/T3/RL9, simulating full pressure delivery from the auxiliary pump, operated contact set /RL9/1 connects +50V, via operated contact set /RL1/2, released contact sets /RL10/2 and /RL6/3, operated contact set /RL2/2, and resistor /R9, to capacitor /C2. This action simulates the recharging of the No.1 system accumulator by the auxiliary pump. If the auxiliary pump is then either switched off or failed, the accumulator discharges in approximately 100 seconds.

20. The "aux. hyd. pump on" relay 14G/T3/RL1 is also energized when the trailing-edge flaps are extending (wing flaps system, Chap.5), or when the landing gear is retracting (landing gear system, Chap.3), when these systems are powered from the No.1 hydraulic system. When the trailing edge flaps are extending, contact set 13F/T1/RL1/3 is operated and relay coil 14G/T3/RL1 is energized from the essential d.c. busbar via circuit breaker SG/113 and the NORM-1 pole of the HYD SYS selector switch AC/BT. Relay /T1/RL1 is de-energized when the flaps reach the fully-extended position, and the auxiliary pump is switched off. Similarly, when the landing gear is being retracted, /RL1 coil is energized via operated contact set 13G/T21/RL12/4 ("gear in unselected position" relay), released contact set 14G/T3/RL4/1 ("U.C. gear release selected" relay, energized only during emergency landing gear extension) and operated contact set 14G/T3/RL3/1. Relay /RL3 is energized when the landing gear control lever AC/BQ is in the LG UP position and contact set 14G/T3/RL4/2 is released. The energizing supply for /RL3 is obtained, via interconnection (4), from the landing gear system when the essential d.c. busbar supplies are available and the LANDING GEAR CONT circuit breaker SG/108 is made. Relay /RL4 is energized, via interconnection (2), when the emergency landing gear release is selected in the landing gear system.

Pressure loss

21. Under certain conditions of hydraulic failure, the selection of hydraulically-operated aircraft services can cause a rapid exhaustion of the No.1 system and accumulator.

22. The coil of relay 14G/T3/RL6 is energized to simulate depletion of the No.1 system accumulator. Provided that the FIRE 2 PULL handle (para.15) is operated and, consequently, contact set /RL2/1 operates, the coil of /RL6 is energized and is maintained energized by contact set /RL6/1, when any of the hydraulically-powered services given in sub-para. (1) to (6), inclusive, are selected. When energized, relay /RL6 can only be de-energized when the FIRE 2 PULL handle is restored to its normal condition, irrespective of the circuit conditions of the hydraulically-powered services. When selected, the following services can cause a rapid depletion of the No.1 hydraulic system accumulator if the No.1 hydraulic system is failed:

(1) Speed brake (extension). When the SPEED BRAKE switch CB/AS is set to the EXTEND position, relay 13F/T1/RL4 is energized in the airbrakes system, (Chap.6), and 14G/T3/RL6 coil is energized via operated contact set 13F/T1/RL4/1 and released contact set /RL3/2. Although contact set /RL3/2 operates when the simulated speed brake is fully extended, relay /RL6 is held-on via operated contact set /RL6/1.

(2) Speed brake (retraction). When the speed brake is in the extended position and the SPEED BRAKE switch CB/AS is set to RETRACT, /RL3 is de-energized and the coil of /RL6 is energized via operated contact set /RL4/1 and released contact set /RL3/2.

(3) Landing gear. Ten seconds after selection of either extension or retraction of the landing gear (Chap.3), the "mainwheels timing" relay 13G/T21/RL1 energizes and contact set /RL1/4 completes the energizing path for the coil of /RL6.

(4) Reverse thrust. If any one of the four reverse thrust actuators (engine thrust system, Part 7, Chap.5) is selected, /RL6 coil is energized via one of diodes /T5/MR1, /MR2, /MR3 or /MR4.

(5) Wheel brakes. Application of either port or starboard brake pedal (wheel brakes system, Chap.4) causes /RL6 to be energized via the appropriate brake pedal microswitch, diode /MR5 or /MR6, and diode /MR7.

(6) Trailing edge flaps. When the trailing edge flaps (wing flaps system, Chap.5) are being extended, relay 13F/T1/RL1 is energized and /RL6 coil is also energized via contact set /RL1/2. In this condition the auxiliary pump is selected automatically (para.20). Similarly, when the trailing edge flaps are retracting, 13F/T1/RL2 energizes and /RL6 also energizes via contact set /RL2/1.

23. Operated contact sets 14G/T3/RL6/2 and /3 connect additional resistors (13F/T7/R6 and /R10, respectively) into the depletion-timing circuits of capacitors /C1 and /C2, respectively; the capacitor discharge-time is effectively shortened (to approximately 0·1 second) to simulate pressure depletion of the auxiliary pump system and the accumulator. The pressure indications reduce to zero accordingly. The No.1 system can then be powered from the auxiliary pump, unless this, too, has been failed by operation of the HYD 1 fail switch. If this switch is operated, /C1 discharges via operated contact set /RL1/1, resistor R4, operated contact sets /RL5/1 ("No.1 hyd. sys. fail" relay) and /RL6/2, and resistor /R6, in approximately 10 seconds.

24. No.1 system pressure is also depleted rapidly if, during failure conditions, aileron or elevator hydraulic boost is applied. Relay 14G/T3/RL10 is energized when either aileron boost or elevator boost is selected in the flying controls and control loading system (Part 9, Chap.1), via diodes /MR9 and /MR10, respectively. With the FIRE 2 PULL handle pulled, capacitor /C2 discharges via operated contact set /RL10/2 and resistor /R12; capacitor /C1 discharges via operated contact set /RL10/1 and resistor /R7. The indicated pressure thus reduces to zero in approximately 10 seconds. The auxiliary pump can then be used to restore the system pressure, if the system has not been failed by means of the instructor's HYD 1 fail switch.

25. The thrust reversers (Part 7, Chap.5) and wheel brakes (Chap.4) are provided with simulated hydraulic accumulators to provide additional emergency operation of these services during hydraulic failure conditions. Description of the simulation of these accumulators is included in the relevant chapters.

NO.2 HYDRAULIC SYSTEM (/016 and /015)

26. The circuit of the simulated No.2 hydraulic system is similar to that of the No.1 system, except for the absence of an auxiliary pump in the No.2 system, which results in a simplification of this circuit. Two discriminators are employed; one, amplifier 13FF/b, energizes relay 14G/T3/RL16 when its input conditions represent No.2 hydraulic pressure equal to 3000 lb/in^2. The second discriminator, amplifier 13FF/a, energizes relay /RL15 at a simulated pressure of 1500 lb/in^2, and de-energizes /RL15 at 1250 lb/in^2.

27. Indication of No.2 system hydraulic pressure is provided by pointer 2 of the twin-pointer hydraulic pressure indicator AC/BH. This pointer is actuated by a servo-driven motor, controlled and powered by amplifier 13FD/b and instrument drive amplifier 13F/T5b.

28. The voltage representing the No.3 engine-driven pump pressure is obtained from the wiper of N_3 potentiometer 14DS/RV5. The voltage from /RV5 wiper is a shaped function, f_5N_3, and is identical to f_5N_2, described in para.10.

29. Capacitor 13F/T8/C2 represents the accumulator fitted to the No.2 system, and is charged to the potential obtained from the N_3 potentiometer, via normally-released contact sets 14G/T3/RL14/1 ("No.2 hyd. sys. fail"), /RL13/3 ("No.3 fire handle selected"), and resistor 13F/T8/R9. The voltage across /C2 is connected to the discriminators and to the instrument servo-amplifier via resistor 13F/T8/R5 and diode /MR2.

30. The voltage, derived from the N_3 potentiometer, that will cause the 1500 lb/in^2 discriminator to switch on and to operate /RL15, is determined by the ratio of the summing resistors connected to the input of amplifier 13FF/a. When /RL15 is in the released state, the summing resistors consist of /R22 (3 megohms), fed by the input voltage, and /R23 (6 megohms), connected to the -50V reference voltage via released contact set /RL15/2. The input, at the junction of /MR2 and /R22, must, therefore, rise to +25V ($\frac{3}{6}$ of 50V) in order to switch on the discriminator. This value of input voltage represents a pressure greater than 1500 lb/in^2; consequently the HYD 2 lamp 13BS/LP15, mounted on the state panel, is lit and /RL17 is operated, via operated contact set /RL15/1.

31. Operated contact set /RL15/2 removes the short-circuit across /R26 and the ratio of summing resistors at the input of 13FF/a becomes 3 : 7·2. To cut off the 1500 lb/in^2 discriminator and release /RL15, the voltage on /R22 must, therefore, be reduced to $\frac{3}{7 \cdot 2}$ of 50V, i.e., approximately +21V. This voltage represents a hydraulic pressure of 1250 lb/in^2.

32. The operation of the 3000 lb/in^2 discriminator and the No.2 system pressure indicator is similar to that of the No.1 system, described in para.8 to 11, inclusive.

33. Failure of the No.2 system, by means of the instructor's HYD 2 fail switch XF/AC/S1, or by operation of the FIRE 3 PULL handle, is achieved in a similar manner to failure of the No.1 system. During failure conditions, capacitor /T8/C2 is discharged at varying rates, dependent upon the states of relays /RL10 ("boost selected", para.24), and /RL7 ("No.2 hyd. sys. reservoir depleted").

34. Operation of the FIRE 3 PULL handle causes the coil of /RL13 to be energized. The coil of /RL7 (/015) can then be energized, via operated contact set /RL13/4, if the wheel brakes or the trailing edge flaps are operated. Operation of /RL7 will cause a rapid discharge of the No.2 system accumulator (capacitor /T8/C2, drawing /016) via contact set /RL7/2. Diode /MR8 isolates the self-holding circuit of /RL7 (operated contact set /RL7/1) from the "wheel brakes" and "flaps" signals.

35. Diode 14G/T5/MR7 prevents /RL7 coil being energized if any of the thrust reversers, landing gear, or speed brake controls are operated; these services are powered only by the No.1 hydraulic system.

36. Operation of the HYDRAULICS TEST switch, /S6, (Part 8, Chap.1), on the state panel 13BS causes both HYD 1 and HYD 2 lamps, 13BS/LP16, (/015) and /LP15, to light; relays 13F/T3/RL12 ("No.1 hyd. available > 1500 lb/in^2", /015) and 14G/T3/RL17 ("No.2 hyd. pressure > 1500 < 1250 lb/in^2") are also operated when this switch is pressed. Operated contact sets of these two relays make the hydraulic systems "available" in the respective aircraft systems which require hydraulics for their operation; these systems can be then tested or serviced with the engine unlit, and without the normal procedural hydraulic selection made.

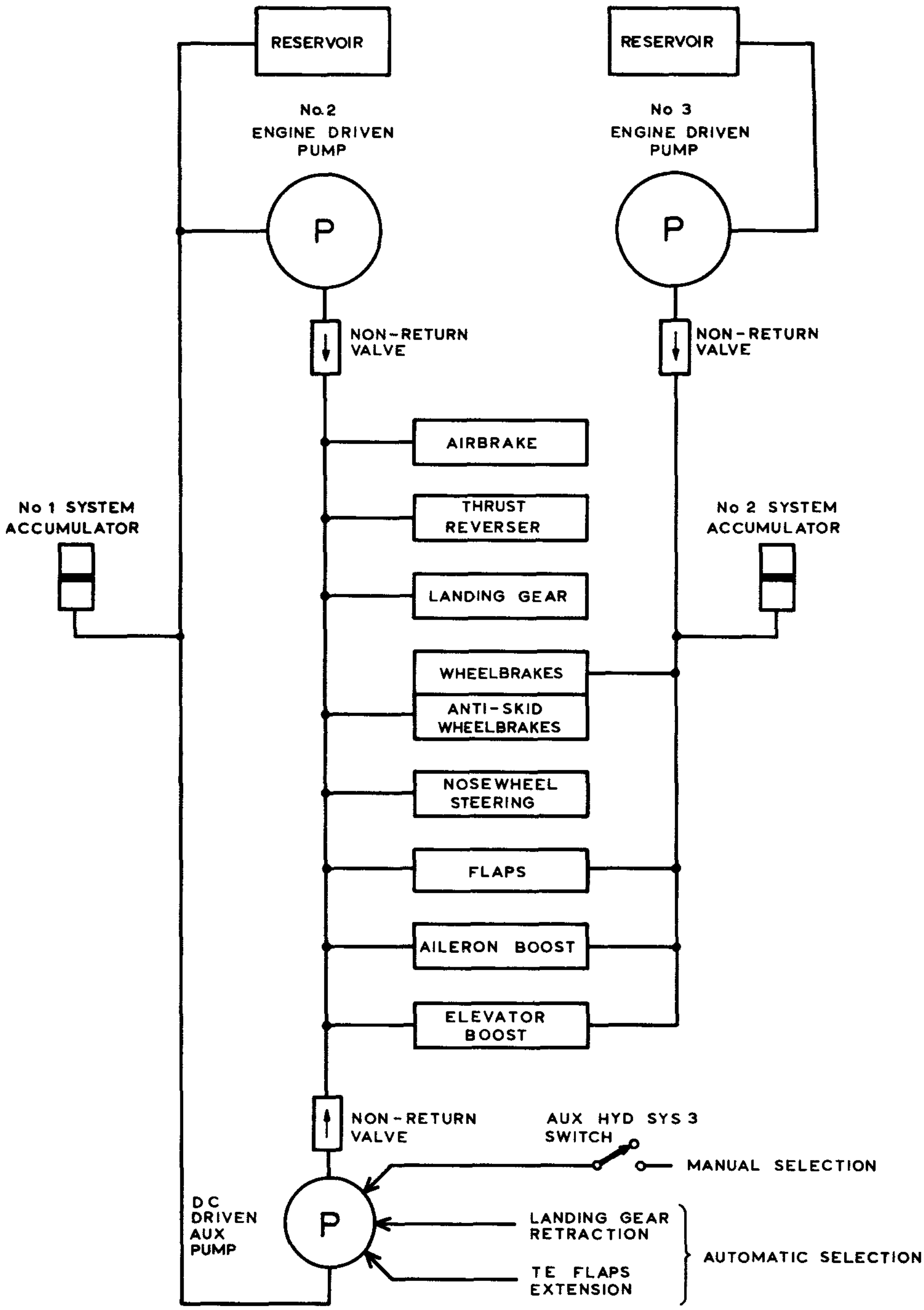


Fig 1 Hydraulic power distribution

Chapter 3

LANDING GEAR SYSTEM

List of Contents

List of Illustrations

Introduction

1. The landing gear system electrically simulates the operation of the hydraulically-actuated tricycle landing gear. The position of the landing gear is controlled by a lever mounted on the co-pilot's main instrument panel. The operative state of the landing gear is indicated by a lamp display; each wheel is represented by a green lamp

that lights when the respective wheel is locked down. A red warning lamp, fitted in the translucent handle of the landing gear control lever, lights when any part of the landing gear is not locked-up nor locked-down, or when the mainwheel doors are not shut. In addition, an audible warning is given when the landing gear is not locked-down, and if any throttle lever is set at less than 40 per cent of its maximum setting; this warning can be cancelled if required.

2. The effects of operation of the landing gear on airspeed and profile noise are simulated in the drag loop system (Part 8, Chap.2) and in the noise system (Chap.11), respectively. Taxi rumble noise is independent of the landing gear system and is controlled by a relay in the height and touchdown system (Part 8, Chap.7).

3. The instructor can fail the operation of either the nosewheel or mainwheels of the landing gear independently. Failure of the simulated hydraulic system supplying the landing gear will immobilize the landing gear system until the emergency GEAR RELease handle is operated. The GEAR RELease, when pulled, allows the landing gear to extend under its own weight and to lock down with the aid of compressed air. The GEAR RELease control consists of a T-handle which is first pulled to a stop to unlock the landing gear; the T-handle can then be turned clockwise through 90° and pulled to a second stop. This last action releases the contents of a compressed-air bottle into the landing gear jacks. The T-handle requires a pull of 70 ± 20 lb.

4. The aircraft can be steered, when on the ground, by the nosewheel steering wheel, PA/AF, which is operative when the main d.c. busbar is energized, the landing gear is selected DOWN, the No.1 hydraulic supply is available, and the aircraft is groundborne. A voltage proportional to the simulated nosewheel angular position, is fed to the yaw loop (Part 8, Chap.5), to represent any change in heading of the aircraft due to operation of the nosewheel steering wheel. Damping is integral with the steering wheel mechanism so that approximately 10 lb-force must be applied, at the rim of the steering wheel, before the simulated nosewheel response occurs. The maximum rate at which the nosewheel can be turned is $50^{\circ}/s$, the limit of rotation being $\pm 53^{\circ}$. The nosewheel steering circuit can be failed by means of the "faultable" LANDING GEAR NOSE STEERING circuit breaker SG/111 (Chap.1).

LANDING GEAR (/009 and /010)

5. The simulated landing gear system cannot become fully operable until the electrical and hydraulic supplies are available, and the simulated aircraft is airborne.

6. Three green lamps, associated with the two mainwheels and the nosewheel, are mounted adjacent to the landing gear control lever on panel AC/BQ of the co-pilot's main instrument panel. These lamps light only when the landing gear is locked down, the nosewheel lamp being operated independently of the two mainwheel lamps.

Independent operation of the mainwheels is not simulated. A red lamp in the landing gear selector lever on panel AC/BQ lights when any part of the landing gear is not locked up or down; this lamp extinguishes when the selected function is correctly terminated.

7. The time taken for the transit of various parts of the landing gear is effected by transistorized relay delay-circuits; the transit times are:

(1) Mainwheel doors opening - 5 seconds
(2) Mainwheels retraction and extension - 10 seconds
(3) Mainwheel doors closing - 5 seconds
(4) Nosewheel retraction and extension - 5 seconds (this figure includes the short period required for the nosewheel door to open and close; these actions are not separately simulated).

Landing gear circuit - normal operation

Initial groundborne conditions

8. When the simulator is first switched on, the landing gear system is automatically set to the locked down condition, with the three green lights lit and the red light extinguished. The system then remains in this condition provided that the landing gear control lever is set to LG DOWN.

9. When the general simulator +27V d.c. supplies are switched on, capacitor 13G/T26/C1 (/009) is charged initially from the +27V supply, via diodes /T26/MR1, /MR2 and /MR3, and the coils of relays /T21/RL3, /RL12, /RL4, /RL9 and /RL16. Relays /RL3 and /RL12 hold on, via operated contact set /RL3/2 and released contact set /RL6/1. Relay /RL4 holds via operated contact set /RL4/1, diode /T23/MR3 and released contact set /T21/RL7/2. Relays /RL9 and /RL16 hold on via operated contact set T21/RL9/2, diode /T23/MR2, and contact set /RL7/2. Operated contact set /RL4/2 connects the earth rail (interconnection (1)) to the circuit of the two mainwheel green lights (para.11).

10. The operation of relays detailed in para.9 has no effect on the indicator lamps, on panel AC/BQ, until the simulated aircraft electrical supplies are available. When the essential d.c. busbar is energized, the coil of /T21/RL19 (/010) is energized via interconnection (2). Contact set /RL19/1 then connects the +27V supply to the landing gear indicator lamps, via circuit breakers SG/109 and SG/110.

11. The two mainwheel indicator lamps are lit via released contact sets /T21/RL18/3 /4, and /RL17/4 which is connected to the earth potential via operated contact set /RL4/2 (/009, para.9). The nosewheel lamp (/010) is also lit, via operated contact

set /T21/RL9/4, and released contact sets /RL18/2 and /T3/RL19/4. Thus, all three green lights are lit, indicating that the landing gear is locked down.

12. Relay /T21/RL20 is energized via contact sets /RL12/1 and /RL16/2, and holds via its own contact set /RL20/1. Thus, with the landing gear control lever set to LG DOWN, and contact set /RL20/2 operated, the landing gear red warning lamp is extinguished.

13. The "mainwheels down" and "mainwheels down, doors closed" conditions are fed to the drag loop (Part 8, Chap. 2). Contact sets/T21/RL4/4 (operated) and /RL6/4 (released) connect +27V to the drag loop system via interconnection (4), thus forming the "mainwheels down" condition. Contact sets /RL12/2 (operated) and /RL13/1 (released) connect +27V to the drag loop system, via interconnection (5), to form the "mainwheels down, doors closed" condition. The "nosewheel down" condition is represented by +27V, fed via operated contact set /RL16/1, released contact set /RL13/2 and interconnection (6), to the noise system (Chap. 11). The effect of the nosewheel on the drag equation is included in the term due to drag of the mainwheels, and is not fed to the drag loop system as a separate signal.

14. The touchdown condition is represented by operated "weight on wheels" relay 13G/T3/RL11; this relay is energized via contact sets 13A/T1/RL5/1 (operated), /RL4/4 (operated) and /RL6/4 (released). The operation of 13A/T1/RL5 is described in the height and touchdown system (Part 8, Chap. 7).

15. When the "No. 1 hydraulics available" relay 13F/T3/RL12 is energized in the hydraulic system, (Chap. 2), +27V is connected to the circuit of the landing gear control-lever switches (/009) via operated contact set 13G/T21/RL19/3 (essential d.c. available), circuit breaker SG/108, operated contact set 13F/T3/RL12/3 (No. 1 hydraulic system available), released contact set 13G/T21/RL11/2, and operated contact set /RL3/4.

16. The initial (groundborne) conditions thus achieved are summarized as follows:

(1) Relays 13G/T21/RL3, /RL12, /RL4, /RL9 and /RL16 operated (/009)
(2) /T21/RL20 operated (/010)
(3) Green lamps lit, red lamp extinguished (/010)
(4) "Mainwheels down" and "mainwheels down, doors closed" signals fed to the drag loop system
(5) "Nosewheel down" signal fed to the noise system
(6) Essential d.c. and hydraulics available
(7) "Weight on wheels" relay /T3/RL11 (/010) operated.

As soon as airborne conditions are simulated, the "weight on wheels" relay /RL11 will be released and the normal landing gear operation can proceed.

Landing gear selected UP

17. Setting the landing gear control lever AC/BQ to the LG UP position lights the red warning lamp, in the translucent handle of the lever, via operated contact set /T21/RL20/2 (/010). Simultaneously, relays /T21/RL7 and 17 (/009) are energized via released contact set /T3/RL11/4 (aircraft airborne) and hold via contact set /RL7/4. Contact set /RL7/2 transfers the hold circuit for /RL4, 9, and 16 to released contact set /RL8/3. The coils of /RL4, 9 and 16 are "slugged" by capacitors /T26/C3 and /C2 to ensure that these relays remain energized during the transition time of contact set /RL7/2, and continue to hold via /RL8/3.

18. The "up cycle in transit" relays /T21/RL6 and 13 are also energized when /RL7 operates, via contact sets /RL7/3 and /RL3/3. Relays /RL3 and 12 tend to de-energize as contact set /RL6/1 changes over, but charged capacitor /T26/C4 "slugs" the relay coils sufficiently to prevent this; relays /RL3, and 12 then hold via contact sets /RL6/1, /RL2/1 and /RL3/2.

19. The "mainwheels down" and "mainwheels down, doors locked" conditions are disconnected from the drag loop system when contact sets /RL6/4 and /RL13/1 operate (/010); contact set /RL13/2 disconnects the "nosewheel down" condition from the noise system.

20. The relay switching actions described in para.17, 18 and 19 are effected when the landing gear control is set to the UP position. Simultaneously, timing circuits operate to simulate the transit times of the mainwheels, the main doors and the nosewheel (/009). In the timing circuit associated with "nose gear timing" /RL8, transistor /VT3 is (initially) cut off due to the positive potential (approximately 20V), obtained from potential divider /R24 and /R25, and fed to /VT3 base via /R23 and the released contact sets connected in series across the timing capacitor /C3. When contact set /RL17/2 operates, -27V is connected via /R21 to capacitor /C3. After approximately 5 seconds, /C3 is sufficiently charged to maintain the junction of /R21 and /R22 negative; /VT3 thus conducts energizing /RL8. Simultaneously, contact set /RL7/1 starts a similar timing sequence in the circuit associated with /RL1.

21. When /RL8 is energized, operated contact set /RL8/3 breaks the holding circuit for relays /RL4, 9 and 16. Contact set /RL4/2 disconnects the earth circuit from the mainwheels green lamps (/010); similarly, contact set /RL9/4 releases and the nosewheel lamp extinguishes. Thus, the 5-second delay from selecting LG UP to the operation of /RL8 (during which time the green lamps remain lit) represents the time taken for the mainwheel doors to open and for the nosewheel to retract.

22. Ten seconds after the selection of LG UP, the "mainwheels timing" relay /RL1 energizes (/009), and contact set /RL1/1 initiates the time delay associated with the "main doors timing" relay /RL2 (in the "landing gear up" sequence, /RL1 has no

other function). After a further 5 seconds, /RL2 energizes and contact set /RL2/1 disconnects the holding circuit for relays /RL3 and /RL12, which then de-energize. Contact set /RL12/1 releases and de-energizes /T21/RL20 (/010); contact set /T21/RL20/2 disconnects the circuit of the red warning lamp, which then extinguishes. Thus, a total of 15 seconds elapses: the first 5-second period (up to the operation of /RL8) represents the time taken for the mainwheel doors to open and for the nosewheel to retract, the next 5 seconds (up to the operation of /RL1) represent the mainwheels retraction-time, and the final 5 seconds (up to the operation of /RL2) are equivalent to the time taken for the mainwheel doors to close.

23. When /RL3 de-energizes (/009), contact set /RL3/4 transfers the energizing supply from pole G to pole X of the landing gear control switch AC/BQ, thus de-energizing relays /RL7 and 17 and making available the +27V supply for subsequent selection of a landing gear extension sequence (/RL10 and 14). Contact sets /RL7/1 and /RL17/2 release and switch off the timing-circuit transistors /VT1 and /VT3. Thus, /RL1 and /RL8 de-energize, and released contact set /RL1/1 causes /RL2 to de-energize by switching-off /VT2.

Note...

The simulated auxiliary boost pump of the No.1 hydraulic system (Chap.2) is switched on automatically when the landing gear is performing a retraction sequence This pump is normally energized by the essential d.c. busbar supplies obtained via circuit breaker SG/108; the circuit of the pump is, therefore, supplied via interconnection (3).

Landing gear selected DOWN

24. At the end of the landing gear retraction sequence, released contact set /T21/RL20/2 connects the earth return of the red warning lamp to pole R of the landing gear control lever switch (/010). Thus, selection of LG DOWN lights the red warning lamp (indicating landing gear in transit) and energizes relay coils /T21/RL10 and /RL14 (/009) which hold via operated contact set /RL10/3.

25. Operated contact set /RL10/1 initiates the 10-second mainwheels timing delay of /RL1, and operated contact set /RL10/2 initiates the timing delay of /RL8. After approximately 5 seconds (simulating the time taken for the nosewheel extension and for the mainwheel doors to open) /RL8 energizes via transistor /VT3. Relays /RL9 and 16 are energized, via operated contact sets /RL14/2, /RL8/1 and diode /MR1, and hold via released contact set /RL7/2 and diode /MR2.

26. After the 5-second period the nosewheel green lamp lights, being energized via contact set /RL9/4 (/010), thus simulating nosewheel extension. In addition, +27V is connected, via operated contact sets /RL8/2, /RL16/1 and released contact set /RL13/2, to the noise system to provide the appropriate airflow noise.

27. When the 10-second mainwheels timing delay has elapsed, /RL1 is energized (/009). Contact set /RL1/1 starts the 5-second "main doors closing" delay associated with /RL2, and contact set /RL1/2 energizes the coil of /RL4 via operated contact set /RL14/2. Relay /RL4 holds via its own contact set /RL4/1, diode /MR3 and released contact set /RL7/2.

28. Operation of contact set /RL4/2 completes the energizing path for the two mainwheels green lamps, and the +27V representing the "mainwheels down" condition is fed to the drag loop system via operated contact sets /RL1/3, /RL4/4 (/010) and released contact set /RL6/4 and interconnection (4). Thus simulation of nosewheel and mainwheels extension is complete, but the red lamp remains lit to indicate that the mainwheel doors are not yet shut.

29. No further action takes place until /RL2 is energized at the end of the 5-second main doors timing delay (/009). When /RL2 is energized, relay coils /RL3 and /RL12 are energized via contact sets /RL2/2, /RL10/4 and /RL6/2, and then hold via released contact set /RL6/1 and operated contact set /RL3/2. Relay coil /T21/RL20 (/010) is energized, via operated contact sets /RL12/1 and /RL16/2, and holds via its own contact set, /RL20/1. The change-over of contact set /T21/RL20/2 thus extinguishes the red warning lamp, indicating that the mainwheel doors are closed. The "mainwheels down" and "mainwheels down, doors closed" signals are fed to the drag loop system as described in para.13.

30. When relay /RL3 is energized, contact set /RL3/4 disconnects the energizing supply from /RL10 and /RL14, which then release; contact set /RL10/1 switches off /VT1 and /RL1 (and, consequently, /VT2 and /RL2), and contact set /RL10/2 switches off /VT3 and /RL8. Contact set /RL3/4 also transfers the energizing supply from pole X to pole G of the landing gear control lever switch, and the system is ready for a subsequent retraction sequence.

Lamp dimming

31. The landing gear indicator lamps (/010) are subject to dimming when the exterior navigational lamps are switched on. Relay 13G/T21/RL18 is operated when the EXTERIOR LIGHTS NAV POS switch, RA/AE, is set to the ON position; operated contact sets /T21/RL18/1, /2, /3 and /4 connect the lamp circuits via dimming resistors. The landing gear "locked down" indicator lamps (green) have a press-to-facility; the red warning lamp can be tested by operation of the HANDLE LIGHT TEST push button, mounted on panel AC/BQ. When /RL18 is energized, a "dimmer" relay in the de-icing system (Chap.8) is also energized via interconnection (7).

Landing gear circuit - emergency operation

Hydraulic failure

32. Should the No.1 hydraulic system fail, the normal functions of the landing gear system are inhibited. If hydraulic failure occurs when the landing gear is locked up, then the landing gear can only be lowered by operating the GEAR RELease lever (para.3) on panel PA. The landing gear cannot be retracted if a hydraulic failure occurs when the landing gear is down; in the following description, it is assumed that the landing gear is locked up when a hydraulic failure occurs.

33. Relay 13F/T3/RL12 is released, in the hydraulic system (Chap.2), when failure of the No.1 hydraulic system is selected and the hydraulic pressure reduces below 1500 lb/in^2. Contact set /T3/RL12/3 (/009) is released and disconnects the +27V supply from the landing gear control lever switch. Selection of LG DOWN fails to energize /R21/RL10 and /RL14 ("down selected" relays); thus the DOWN cycle is inhibited. The red warning lamp (/010) lights via /T21/RL20/2 and switch AC/BQ, however, to indicate that the landing gear is in an unsafe condition.

34. When the GEAR RELease handle PA/AD is pulled to its first stop, switch XA/AC/S1 is operated (/009); relays /RL5 and /RL11 are energized, and hold via operated contact set /RL5/3. These relays obtain their energizing current from the +27V general supply via the RESET SYSTEMS switch XF/AM/S7 (airbrakes system, Chap.6) on the flight instructor's console. Contact set /RL11/2 breaks the energizing supply to relays /RL10, 14, 7 and 17 to prevent further landing gear operation by means of the landing gear control lever. When the emergency gear release system is used, the +27V supply is also fed, via interconnection (4), to the hydraulic system (Chap.2) to inhibit the operation of the auxiliary boost pump (para.23).

35. Contact set /RL5/2 initiates the 10-second mainwheels delay (/RL1), and, simultaneously, released contact set /RL11/1 initiates the 5-second delay of /RL8. After 5 seconds, representing the time taken for the nosewheel to be blown down by the slipstream, /RL8 is energized, and operated contact set /RL8/1 connects the +27V supply, via operated contact set /RL11/3, to energize relays /RL9 and 16. Operated contact set /RL9/4 lights the nosewheel green lamp (/010), and the "nosewheel down" noise signal is fed to the noise system via /RL16/1 and /RL13/2.

36. To extend the mainwheels, it is necessary to pull the GEAR RELease handle to a second stop and turn it clockwise through 90°. This last action operates microswitch XA/AC/S2 and energizes relay /RL15, which then holds via /RL15/1 and /RL5/4. When /RL1 is energized (/009), after the 10-second delay, contact set /RL1/2 operates and energizes /RL4 via /RL15/2. Relay /RL4 holds (para.27), and the mainwheels green lamps light (para.28).

37. Contact set /RL1/1 starts the 5-second delay of /RL2 as in the normal extension sequence (para.27). Relays /RL3 and 12 are energized when contact set /RL2/2 operates (para.29), released contact set /RL10/4 being by-passed, in the "emergency" sequence, by operated contact set /RL15/4.

38. Operated contact set /RL12/1 energizes /RL20 (/010), via contact set /RL16/2, and the red warning lamp is extinguished, thus indicating that the mainwheel doors are down and locked.

39. The landing gear system circuit must be reset (after operation of the GEAR RELease handle) by means of a mechanical reset lever, located below panel XF/AH, and by operation of the RESET SYSTEMS switch (para.34), which releases /RL5, /RL11 and /RL15. The system is then restored to the normal locked down condition.

Failure of mainwheel doors to unlock

40. The instructor can simulate the mainwheel doors failing to unlock by operation of MAIN WHEELS DOOR UNLOCK fail switch XF/AC/S6 (on the flight instructor's console, /009). If landing gear DOWN is now selected, the red warning lamp lights, the nosewheel timing circuit operates as in the normal "down" cycle and, after 5 seconds, /RL8 is energized and the nosewheel lamp lights. The mainwheels timing circuit (/RL1) is inhibited by switch XF/AC/S6; thus the "down" cycle is not allowed to proceed. The mainwheels can be "lowered and locked" by operation of the GEAR RELease handle, as for hydraulic failure (para.32).

Failure of nosewheel to lock down

41. Simulation of the nosewheel failing to lock down is achieved by operation of the NOSE WHEEL fail switch XF/AC/S4 (on the flight instructor's console) when the landing gear is locked up (/010). Subsequent selection of LG DOWN causes the mainwheels to extend and lock, and the nosewheel to extend but not lock. The nosewheel can then be locked by operation of the GEAR RELease handle (para.32).

42. When the landing gear is locked up, relay /T21/RL20 (/010) is in the de-energized state, because contact sets /RL12/1 and /RL16/2 are released (para.22). Operation of the NOSE WHEEL fail switch provides energizing current for the coil of relay /T3/RL19 via XF/AC/S4 and released contact sets /T21/RL11/4, /T3/RL18/3 and T21/RL20/4. If the landing gear control lever is now set to the LG DOWN position, a "down" cycle begins and proceeds as described in para.24 to 30. The nosewheel lamp is prevented from lighting, however, by operated contact set /RL19/4, and the nosewheel thus appears to be not locked down. Operated contact set /RL19/3 ensures that the red warning lamp remains lit.

43. The nosewheel can be locked down by pulling the GEAR RELease handle to its first stop, causing /RL11 to be energized and contact set /RL11/4 to de-energize /RL19. Contact set /RL19/4 then releases, and the nosewheel green lamp lights. Similarly, contact set /RL19/3 releases and the red warning lamp extinguishes. The system can be restored to its normal condition by operation of the RESET SYSTEMS switch, etc., as described in para.39.

Failure of mainwheels to lock down

44. Operation of the MAIN WHEELS fail switch XF/AC/S5 (on the flight instructor's console), when the landing gear is locked up, prevents the mainwheels green lamps being lit, and causes the red warning lamp to remain lit, at the end of a subsequent "down" cycle. The mainwheels thus appear to be not locked down (i.e., somewhere in transit), and can then only be locked down by operation of the GEAR RELease handle.

45. Operation of switch XF/AC/S5 (/010) causes the "fail lock down (m.w.)" relay coil /T3/RL17 to be energized via released contact sets /RL15/3, /T3/RL18/2 and /T21/RL20/3. Relay /T3/RL17 is self-holding via contact set /RL17/1.

46. Selection of landing gear LG DOWN initiates a "down" cycle which proceeds as described in para.24 to 30. At the end of the first 5 seconds, the nosewheel lamp is lit via contact set /RL9/4, but when the complete timing sequence terminates, operated contact set /T3/RL17/4 prevents the two mainwheel green lamps lighting. In addition, operated contact set /RL17/3 causes the red warning lamp to remain lit.

47. The extension and locking of the mainwheels can be completed by pulling the GEAR RELease handle to its second stop. This action energizes /RL15, and operated contact set /RL15/3 breaks the energizing current for /RL17, which then releases. Released contact sets /RL17/4 and /3 cause the mainwheel green lamps to light and the red warning lamp to extinguish.

48. The system can be reset to its normal condition by restoration of the GEAR RELease to its normal position and operation of the RESET SYSTEMS switch, etc., (para.39).

Failure of mainwheels or nosewheel to lock up

49. Operation of either the MAIN WHEELS or the NOSE WHEEL fail switch, when the landing gear is locked down, results in the apparent failure of the landing gear during a subsequent "up" cycle. The green lamps extinguish indicating that the nose-wheel and mainwheels are unlocked, but the red warning lamp remains lit. The

landing gear must then be reselected DOWN, which results in a normal "down" cycle, at the end of which the three "down and locked" green lamps light and the red warning lamp extinguishes.

50. When the landing gear is locked down, /T21/RL20 (/010) is in the energized state Thus, operation of either MAIN WHEELS or NOSE WHEEL fail switches operates /T3/RL18 via diode /T6/MR57 (mainwheels) or diode /T6/MR58 (nosewheel), released contact sets /T3/RL17/2, /T3/RL19/2, and operated contact set /T21/RL20/4. Relay /T3/RL18 is self-holding via operated contact set /RL18/1.

51. A selected UP cycle proceeds and terminates normally, as described in para. 17 to 23. Contact set /T21/RL20/2 releases at the end of the "up" cycle, but the red warning lamp remains lit, due to operated contact set /T3/RL18/4. If the landing gear control lever is now selected DOWN, the red lamp remains lit, via released contact set /T21/RL20/2, and a normal "down" cycle proceeds, at the end of which the green lamps light and the red warning lamp extinguishes. Operated contact sets /RL18/2 and /RL18/3 prevent relays /RL17 and /RL19 being energized during the extension sequence following the failure to lock "up".

Audio warning

52. A normally-open microswitch is fitted to each of the four throttle levers; these microswitches close when the respective throttle lever is at less than 40 per cent of its maximum setting. If any part of the landing gear is retracting or retracted when one or more of the throttle lever microswitches operate, the "U/C audio warning" relay 13G/T3/RL20 is energized, and switches on an audible warning signal. Simultaneously, the red warning lamp is lit via operated contact set /T3/RL20/2 and released contact set /RL6/3. Relay /T3/RL20 obtains its energizing current from the +27V supply via operated contact set /T21/RL19/3, circuit breaker SG/108, and the respective operated throttle lever microswitch. The earth return for /T3/RL20 is connected via released contact set /RL6/2, and one or both of contact sets /T21/RL4/2 (released when the mainwheels are retracted) and /T21/RL9/3 (released when the nosewheel is retracted). Operation of the WARNING SILENCER push-button AC/BQ energizes relay /T2/RL6 which holds via /RL6/1. Operated contact set /RL6/2 de-energizes /T3/RL20 and the audible warning is suppressed. The red warning lamp in the landing gear control handle remains lit, however, being energized via released contact set /RL20/2 and operated contact set /RL6/3.

<u>NOSEWHEEL STEERING - CIRCUIT</u> (/016)

53. A voltage proportional to the angular position of the nosewheel steering wheel, PA/AF, is obtained from the wiper of potentiometer XB/AA/RV1 and is fed to the yaw

loop (Part 8, Chap.5) via contact set 14G/T3/RL18/2. When the steering wheel is turned to the left this voltage is positive; when the steering wheel is turned to the right, the voltage is negative, the voltage is zero when the nosewheel is centralized.

54. Four AND-connected contact sets must be operated to energize the coil of "nosewheel steering available" relay /T3/RL18. These contact sets are 13G/T5/RL16/2 of the circuit of the NOSE STEERING faultable circuit breaker SG/111 (which can be failed by the instructor's LANDING GEAR switch XF/AK/S17, electrical system, Chap.1), 13A/T1/RL10/2 ("nosewheel touchdown"), 14G/T3/RL19/1 ("landing gear down selected") and 14G/T3/RL8/2 ("No.1 hydraulics available"). If contact sets 13G/T5/RL16/2 and 14G/T3/RL8/2 are operated, the availability of the nosewheel steering analogue voltage then depends on the operation of 14G/T3/RL19 and 13A/T1/RL10.

55. When the nosewheel is locked down, relay 13G/T21/RL16 is energized (para.25) The coil of 14G/T3/RL19 is energized from the +27V general supply, via operated contact set 13G/T21/RL16/3 and released contact set 13G/T21/RL17/1, and /RL19 holds via operated contact set /RL19/2. When touchdown conditions have been achieved, the "nosewheel touchdown" relay 13A/T1/RL10 is operated in the height and touchdown system (Part 8, Chap.7), provided that the mainwheels are also on the ground; thus, operated /RL10 represents the complete landing gear touchdown condition. When contact set /RL10/2 operates, the coil of 14G/T3/RL18 is energized and the nosewheel steering signal becomes available.

56. When the airborne state is subsequently simulated and the landing gear control lever is set to UP, contact set 13G/T21/RL17/1 operates and breaks the energizing circuit to the coil of 14G/T3/RL19. Relay /RL19 is thus de-energized and the "nosewheel steering available" relay /T3/RL18 is, subsequently, also de-energized.

57. In the event of an hydraulic or electrical failure occurring while the aircraft is being steered on the ground, /RL18 releases and the nosewheel steering signal is disconnected (by released contact set /RL18/2), thus representing the castoring action of the nosewheel.

Chapter 4

WHEEL BRAKES SYSTEM

List of Contents

List of Illustrations

Introduction

1. The mainwheels are braked by conventional hydraulically-operated disc brakes with anti-skid protection. The brakes are normally powered by the No.1 (normal) hydraulic system, but can also be operated from the No.2 (stand-by) hydraulic system, selected by a switch on the instrument panel, in the event of a No.1 hydraulic system failure. Anti-skid protection is not available, however, when the brakes are operated by the stand-by hydraulic system.

2. The brakes are actuated together or differentially, by the pilot's (and co-pilot's) brake pedals. A parking brake is also provided and is operated, after the application of foot pressure to both pedals, by pulling a locking handle. The locking handle, which requires a pull force of 25lb, moves through approximately 3 inches.

3. Back-up power is provided in the normal hydraulic supply to the wheel brakes by means of the wheel brakes hydraulic accumulator. The accumulator is charged by the

normal hydraulic system only, and will provide for up to 4 brake pedal applications following a failure of the No.1 hydraulic system. The accumulator pressure will then be less than 1250 lb/in^2. No indication of brake pressure is given other than the engraved BRAKE PRESS LOW warning, on the annunciator warning panel, which is illuminated when the brake accumulator pressure falls below 1250 lb/in^2. When the brakes are operated from the No.2 (stand-by) hydraulic system, the BRAKE PRESS LOW warning is illuminated immediately the stand-by hydraulic system pressure falls below 1250 lb/in^2. The BRAKE PRESS LOW warning will extinguish when the pressure to the wheel brakes rises again to 1500 lb/in^2, irrespective of the hydraulic system selected.

4. The simulated wheel brakes system electrically fulfils the functions of the aircraft system. In addition, the instructor can fail the wheel brakes system, when this is operated from the normal hydraulic supply, by use of the BRAKES fail switch on the flight instructor's panel. No warning of this failure is given, however, until the simulated accumulator has been discharged by 4 brake pedal applications, at which point the brakes become inoperative until the pilot selects the stand-by hydraulic system. Failure of the wheel brakes system, when powered by the stand-by hydraulic system, is not simulated, except by failure of the stand-by hydraulic system itself.

CIRCUIT DESCRIPTION (/014)

Operation from normal hydraulics

5. Each brake pedal actuates a potentiometer, from which a positive voltage, proportional to the force applied to the pedal, is obtained and fed to the drag loop (Part 8, Chap.2), and to the yaw loop (Part 8, Chap.5). The two potentiometers are supplied with +50V via contact set 13A/T1/RL7/3, operated when the mainwheels touch down.

6. The port brake signal is fed from the wiper of XC/AD/RV1, via XC/AD/R1, and contact set 13F/T1/RL8/2; the starboard brake signal is fed from the wiper of XL/AD/RV1, via XL/AD/R1, and contact set /RL8/1. Both potentiometers are operated simultaneously by the parking brake. Under normal conditions, the coil of relay /RL8 ("wheel brakes available") is energized via released contact sets /RL5/1 ("No.1 hydraulics off") and /RL7/2 ("brake force zero"). Relay /RL5 is energized only when the hydraulic system is switched to STANDBY-2; /RL7 energizes when the hydraulic accumulator has been discharged by 4 brake-pedal operations during a No.1 hydraulic system failure.

7. Relay /RL7 is also energized when the simulator +27V supply is switched-on, the coil being energized, via diode 13F/T2/MR8, by the charging current for capacitor 13F/T2/C4. Similarly, relay 13F/T1/RL10 is energized at switch-on, by the

charging current of 13F/T2/C3; /RL10 is held-on via operated contact set /RL10/1 and released contact set 14G/T3/RL8/3. Relay /RL7 therefore holds via operated contact sets /RL7/1 and /RL10/3; /RL8 is de-energized and the wheel brake signals are initially disconnected from the drag loop and the yaw loop when the hydraulic pressure is less than 1500 lb/in^2.

8. When the No.1 hydraulic system pressure exceeds 1500 lb/in^2, relay 14G/T3/RL8 is energized (hydraulic system, Chap.2). Operated contact set 14G/T3/RL8/3 breaks the holding circuit for the coil of /T1/RL10; /RL10 de-energizes and the coil of /RL7 is de-energized by released contact set /T1/RL10/3. Relay 13F/T1/RL8 is energized via released contact sets /RL7/2 and RL5/1,. and the wheel brakes signals become available via operated contact sets /RL8/1 (starboard) and /RL8/2 (port). The wheel brakes signals remain available until either the No.1 hydraulic system pressure falls below 1500 lb/in^2 or the instructor fails the wheel brakes system.

<u>No.1 hydraulic system failure</u>

9. If the No.1 hydraulic system pressure falls below 1500 lb/in^2, relay 14G/T3/RL8 de-energizes and contact set /RL8/3 connects +27V, via released contact set 13F/T1/RL10/4, to a counting circuit that simulates the hydraulic accumulator. Of the eight relays used in the counter, four - 13F/T3/RL11, /RL13, /RL14 and /RL15 - are associated with the port brake pedal; the remaining four relays - /RL16, /RL17, /RL18 and /RL19 - are associated with the starboard brake pedal.

10. The purpose of the counting circuit is to count the total number of brake operations and to release the "wheel brakes available" relay, 13F/T1/RL8, when the count reaches four. The total can be achieved in four different ways; by four operations of either pedal, two separate operations of each pedal, one operation of one pedal plus three operations of the other pedal, or two simultaneous operations of both pedals. The counting circuit is symmetrical, the circuit associated with the port pedal being similar to that of the starboard pedal (except for component references); only the port circuit is described. For the purpose of circuit explanation, four applications of one pedal have been assumed; simultaneous application of both pedals is, however, the more common use of the brakes.

11. Operation of the port brake pedal actuates microswitch XC/AD/S1. The first operation of /S1 applies +27V, via released contact set 13F/T1/RL5/2 (para.20), to the coils of relays /RL11 and /RL13, via diode 13F/T1/MR3. Relay /RL11 coil energizes and holds via contact set /RL11/1, but /RL13 coil cannot energize at this time because +27V is also applied to the earthy end of its winding, via released contact set /RL13/1. When the pedal is released, /S1 contact breaks; /RL13 coil now energizes, via operated contact set /RL11/1. Thus, after one pedal operation and release, both relays /RL11 and /RL13 are energized.

12. When the port pedal is operated for the second time, /RL11 is de-energized, because +27V is applied to one end of its coil via operated contact set /RL11/1 and, simultaneously, to the other end via operated contact set /RL13/1. The energizing circuit for /RL13 is now transferred to /S1 and /MR3. Released contact set /RL11/2 and operated contact set /RL13/2 now apply +27V to the coils of /RL14 and /RL15; /RL14 coil energizes via /MR4 and holds via operated contact set /RL14/1, but /RL15 remains de-energized, there being +27V on both ends of its coil. When the pedal is released for the second time, /RL15 energizes and holds via operated contact set /RL14/1; /S1 breaks the energizing circuit for /RL13, which then releases. Thus, after the port rudder pedal has been operated and released twice, relays /RL14 and /RL15 are energized, and /RL11 and /RL13 are de-energized.

13. The sequence of operation of relays /RL11 and /RL13, described in para.11, is repeated when the port pedal is operated and released for the third time. When the pedal is operated for the fourth time, relays /RL11 and /RL14 are de-energized relays /RL13 and /RL15 remain energized. The coil of "No.1 hydraulics less than 1500 lb/in^2 and brakes used 4 times" relay, 13F/T1/RL10, now energizes, via operated contact set /RL15/2, released contact set /RL14/3, and released contact set 14G/T3/RL8/3. The "brake force zero" relay 13F/T1/RL7, energizes, via operated contact sets /T1/RL10/3 and /T3/RL15/3. The "wheel brakes available" relay, 13F/T1/RL8 is thus de-energized by operated contact set /RL7/2, and the simulation of the hydraulic accumulator depletion, in this example, by four port brake operations, is complete.

14. The circuit operation described in para.11 to 13, inclusive, is illustrated by the timing diagram (Fig.1): the heavy lines represent the operation of relay or switch contacts, on an arbitrary time scale. The various combinations of pedal operation that will cause /RL10 to energize are described by the Boolean equation:

$$(10) = \left\{ (11) \cdot (16) \right\} \cdot \left[(14) + (18) \right] + \left\{ (19) \cdot (\overline{18}) \right\}$$

$$+ \left\{ (14) \cdot (18) \right\} + \left\{ (\overline{14}) \cdot (15) \right\}$$

In this equation, the numbers in the curved brackets, thus: ( ), refer to relays 13F/T1/RL10, /T3/RL11, 14, 15, 16, 18 and 19, in their energized states; numbers in these brackets with negate bars, thus: $(\overline{14})$, refer to relays in their de-energized states. The Boolean symbols + (OR) and · (AND) are also used. The equation, therefore, states that relay /RL10 is operated when any one of the four conditions in brace-type brackets is satisfied. For example, one of these conditions is when /RL14 is de-energized AND relay /RL15 is energized. This is represented in the equation by: $\{(\overline{14}) \cdot (15)\}$. The alternative paths for the energizing supply to relay /RL10 conform to the remaining terms of the equation.

Note...
Further reference to Boolean logic is given in Part 12, Chap.3.

15. When /T1/RL10 energizes, contact set /RL10/2 closes and completes the energizing path, via the B1 contact of the HYD SYS selector switch AC/BT and interconnection (2), to the BRAKE PRESS LOW lamp on the annunciator warning panel (Part 9, Chap.5). This lamp then lights, indicating failure of the normal hydraulic system and depletion of the hydraulic accumulator.

16. Contact set /RL10/4 releases and disconnects the supply to the relays comprising the counting circuit. All relays in the counter are thus de-energized and the counter circuit is reset.

17. Failure of hydraulic supply to the wheel brakes can be simulated by operation of the BRAKES fail switch XF/AC/S7 which is mounted on the flight instructor's panel. When closed, this switch duplicates the action of contact set 14G/T3/RL8/3 described in para.8; the subsequent circuit operation is as described in para. 9 to 16, inclusive. Relay 13F/T1/RL10 holds via contact set RL10/1 and either operated contact set 14G/T3/RL8/3 or the BRAKES fail switch. Relay /RL10 thus remains energized until either the hydraulic pressure from No.1 system is restored to 1500 lb/in^2 (/RL8 released), or the fail switch is released.

Anti-skid

18. The anti-skid facility, which is available only with the normal hydraulic system selected, is simulated by relay 13F/T1/RL6. This relay is energized when the ANTI SKID switch, AS/AP, is closed and the HYD SYS selector switch AC/BT is set to NORM-1. Contact set /RL6/1 is connected, via interconnection (1), to the ANTI SKID OUT lamp on the annunciator warning panel; the lamp normally remains extinguished when the anti-skid facility is in use. If the anti-skid facility is switched off by either the ANTI SKID switch or the HYD SYS selector switch, the lamp lights via released contact set /RL6/1.

Operation from stand-by hydraulics

19. After a failure of the No.1 hydraulic system and its backing-up accumulator, further operation of the wheel brakes can only be effected by the No.2 (stand-by) hydraulic system. The No.2 system is selected by setting the HYD SYS selector switch to STANDBY-2; under these conditions, 13F/T1/RL5 is energized and 13F/T3/RL10 is de-energized. The normal energizing path for the coil of "wheel brakes available" relay, /T1/RL8, is open-circuited when contact set /RL5/1 operates; contact set /RL10/1 is released, however, and the availability of the wheel

brakes is dependent on contact set 14G/T3/RL17/2.

20. Relay 14G/T3/RL17 is energized when the stand-by hydraulic pressure reaches 1500 lb/in^2 and remains energized unless this pressure falls below 1250 lb/in^2; the wheel brakes are thus available under stand-by conditions unless the pressure is reduced below 1250 lb/in^2. There is no backing-up accumulator for the brakes when powered by the No.2 system; this absence of hydraulic pressure reserve is simulated by the inclusion of contact set 13F/T1/RL5/2 in series with the +27V supply to the "accumulator discharge" counter circuit. Operated contact set /RL5/2 disconnects the counter circuit from its supply if the No.2 hydraulic system fails.

21. If the No.2 hydraulic system fails when supplying the wheel brakes system, the BRAKE PRESS LOW lamp is lit via contact set 14G/T3/RL17/1 and contact B3 of the HYD SYS selector switch. The coil of relay /RL17 is included in the circuit of the hydraulic system (Chap.2).

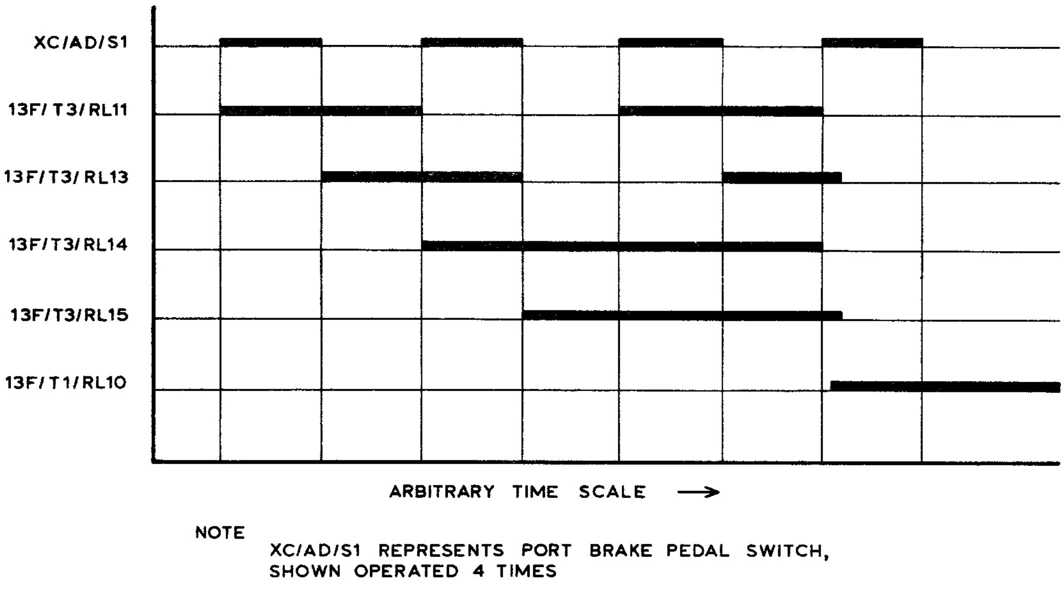


Fig 1 Counter timing diagram

Chapter 5

WING FLAPS SYSTEM

List of Contents

List of Illustrations

Introduction

1. The wing flaps system simulates the function and effects of the electrically-actuated, hydraulically-operated leading edge and trailing edge wing flaps. Extension and retraction of both sets of flaps is controlled by a single FLAPS control lever, mounted on the co-pilot's side of the throttle pedestal. The FLAPS control lever assembly contains six cam-operated microswitches; five of these switches are used in the flaps system and one is connected in the pitch trim and Mach trim compensator circuit (trimming systems, Part 9, Chap.2). The microswitches control sequence relays which ensure that the leading edge flaps extend fully before extension of the trailing edge flaps commences and, conversely, the trailing edge flaps are fully retracted before retraction of the leading edge flaps commences.

2. Two flaps position indicators are mounted on the centre instrument panel. The LE FLAPS indicator AC/BL is a moving-coil instrument driven directly by the output of an integrating amplifier, the delay characteristic of which simulates the leading edge flaps extension and retraction times. The TE FLAPS indicator AC/BM is also a moving-coil instrument, but is driven by the voltage derived from the wiper of a servo-driven Δ potentiometer. This potentiometer is one of three four-ganged potentiometers which are driven by the trailing edge flaps actuator which is in turn controlled by a servo amplifier.

3. The wing flaps can be operated from either the normal or stand-by hydraulic system, depending upon the setting of the HYD SYS selector switch AC/BT. When operating from the normal (No.1) hydraulic system, leading edge flaps extension or retraction takes 7·5 seconds whereas full extension or retraction of the trailing edge flaps is completed within 15 seconds. When operating from the stand-by (No.2) hydraulic system, the trailing edge flaps extension or retraction times are increased to 25 seconds, the leading edge flaps then being controlled directly by the trailing edge flaps sequence relays (para.1). In addition, the electrically-driven hydraulic pump is switched on automatically during trailing edge flaps extension.

4. The flaps system can be failed by operation of the flight instructor's FLAPS switch XF/AC/S8. If this switch is operated (or if the electrical supply from the simulated main d.c. busbar fails) the pointers of the flaps position indicators rotate to their fully-clockwise position (para.7).

WING FLAPS SYSTEM (/013)

5. The wing flaps circuit includes:

(1) An electronic integrator for simulation of leading edge flaps extension and retraction

(2) A positional servo for simulation of trailing edge flaps extension and retraction, and the provision of the Δ signals (trailing-edge flaps deflection angle) for the flight computer circuits

(3) A relay circuit which ensures that the flaps indications are given in the correct sequence.

Hydraulic and electrical supplies

6. To operate the flaps, the main d.c. busbar must be energized and connected to the flaps system, and sufficient hydraulic pressure must be available.

7. The +27V supply representing the main d.c. busbar supply is fed to the flaps system provided that:

(1) The FLAPS fail switch XF/AC/S8 is in the off position (as shown on /013)

(2) "Main d.c. available" relay 13F/T3/RL1 is operated

(3) "LE and TE CB intact" relay 13G/T5/RL18 is operated (electrical system, Chap.1).

If these conditions are satisfied, the +27V supply is routed to microswitches /S1 to /S5 of the FLAPS lever CB/AV, via the HYD SYS selector switch AC/BT and circuit-isolating diodes, and also to relay 13F/T3/RL2; if this relay is de-energized due to any one of the conditions stated in sub-para. (1) to (3) not being met, released contact sets /RL2/1 and /2 connect a bias current to the LE FLAPS and TE FLAPS indicators, to hold the pointers in their fully clockwise positions.

8. The electrical supply from the HYD SYS selector switch AC/BT is routed to relay 13F/T3/RL20, via 14G/T3/RL8/4 ("No.1 hyd available") and diode /T1/MR1 when the No.1 hydraulic system is selected, or, when the No.2 hydraulic system is selected, via 14G/T3/RL17/3 ("No.2 hyd. available") and diode /T1/MR2. Thus, /RL20 is energized when the selected hydraulic system is available at normal working pressure, i.e., in excess of 1500 lb/in^2. Contact sets /RL20/1 and /RL20/2 operate in the input circuit of the LE flaps integrator and in the TE flaps actuator circuit, respectively, and cause the LE FLAPS and TE FLAPS indicators to "freeze" in the event of simulated hydraulic failure.

Flaps control lever

9. The FLAPS control lever, CB/AV, is fitted with click-stops at three positions of its travel. The first click-stop is at the LEADING EDGE UP position; when the control lever is in this position, all flaps are fully retracted, and the microswitches are as shown in Fig.1. The other two click-stops are at the TAKE OFF/APPROACH and the LANDING (trailing edge flaps down) positions of the FLAPS control lever. The control lever can also be set to an intermediate position, LEADING EDGE DN; this setting corresponds to TRAILING EDGE UP and has no click-stop. A sixth microswitch, CB/AV/S6, is operated when the control lever is in the TAKE OFF/APPROACH position; this microswitch, which is not shown on the wing flaps circuit diagram (/013), operates in the pitch trim and Mach trim compensator circuit, to ensure that the tailplane trim angle is limited to a maximum of 4^{o} nose-up when the wing flaps are at less than the TAKE OFF/APPROACH angle (trimming systems, Part 9, Chap.2).

Operation from the normal hydraulic system

10. With the electrical and hydraulic supplies connected, and with the FLAPS control lever set to the LEADING EDGE UP position, released contact set 13F/T3/RL5/3 and operated contact set /RL20/1 connect +50V to the summing input of integrating amplifier 13FB/a, the output of which tends to be negative but is limited to 0V by diode 13F/T4/MR3. Transistor /VT1 is thus cut off, 13F/T6/RL4 is de-energized, and the pointer of the LE FLAPS position indicator, AC/BL, is at UP (fully counter-clockwise). (The TE FLAPS position indicator, AC/BM, also indicates UP at this time, due to the position of the wiper of Δ potentiometer 13AS/a/RV1b).

Extension of wing flaps

11. Microswitch /S1 opens when the control lever is advanced approximately a quarter of an inch beyond its LEADING EDGE UP position, and the operation of relay 13F/T3/RL4 is then controlled by relay 13F/T3/RL5. When the control lever is set to the LEADING EDGE DN position, /S2 closes and the coil of /RL5 is energized. Relay /RL4 de-energizes when contact set /RL5/2 releases; /RL5 then holds via operated contact set /RL5/1 and released contact set /RL4/2.

12. Operated contact set /RL5/3 connects -50V to the input of the integrating amplifier, 13FB/a. The output of the integrator begins to increase positively and, during this time, the pointer of the LE FLAPS position indicator rotates clockwise, simulating the extension of the leading edge flaps. After 7·5 seconds, the integrating amplifier output reaches +100V and is limited to this value by /MR4, /R5 and /R6; the pointer of the LE FLAPS indicator is then at the take-off and approach/landing (TO APP LDG) position. Transistor /VT1 conducts, energizing the coil of relay /T6/RL4. Operated contact set /T6/RL4/1 connects the trailing edge flaps actuator motor 13AS/a/X1 to the output of power amplifier 13AS/a, thus allowing the actuator to be driven only when the leading edge flaps are fully extended.

13. When the FLAPS control lever is moved to the TAKE OFF/APPROACH position, /S4 closes and /T3/RL7 is energized. Operated contact set /RL7/2 disconnects the holding circuit to the coil of /T3/RL6, which then de-energizes (/S3 opens at a point just beyond the LEADING EDGE DN/TRAILING EDGE UP position of the control lever)

14. Operated contact set /RL7/4 connects +50V, via scaling resistor /T4/R24, to the input of amplifier 13FB/b; the output of power amplifier 13AS/a increases negatively and the trailing edge flaps actuator motor 13AS/a/X1 operates. The amplifier output voltage is limited to -27V by feedback-limiting network /MR6, /R26, /R27 and /R28. The trailing edge flaps actuator motor drives three four-ganged potentiometers, 13AS/a/RV1a - d, /RV2a - d and /RV3a - d, inclusive. Potentiometer /RV1a is the positional feedback potentiometer for the trailing edge

flaps servo loop, and /RV1b provides the drive current for the TE FLAPS position indicator AC/BM. The remaining potentiometers are used in the flight computer (Part 8) to provide various functions of Δ.

15. Transistor /VT2 conducts and operates relay /T6/RL6 ("TE flaps extending") as soon as the amplifier output exceeds -5V. Contact set /T6/RL6/1 operates and the coil of "TE flaps extending" slave relay, /T1/RL1, is energized. Contact sets of /RL1 operate in the hydraulic system (Chap.2) and automatically switch on the auxiliary hydraulic pump. Contact sets of /RL1 are also used to discharge the capacitor, that simulates the No.1 hydraulic system accumulator, in the event of a No.1 hydraulic system failure.

16. The trailing edge flaps servo reaches a null-point six seconds after operation of relay /T3/RL7 (para.13). Relay /T6/RL6 and slave relay /T1/RL1 de-energize when the output of the servo amplifier reduces to zero. The pointer of the TE FLAPS indicator reaches the TO APP (take-off and approach) position which corresponds to 40 per cent of the trailing edge flaps maximum extension.

17. To fully extend the trailing edge flaps, the control lever is moved to the LANDING position. When the control lever is at a position just beyond TAKE OFF/APPROACH, /S4 opens; /RL7 is held-on via released contact sets 14F/T3/RL8/2 and /T3/RL6/2, and operated contact set /RL7/1. Relay /RL8 is operated by /S5 when the control lever is in the LANDING (DN) position; /RL7 coil de-energizes when contact set /RL8/2 disconnects its holding circuit.

18. Operated contact set /RL8/4 connects +50V, via scaling resistor /R23, to the input of amplifier 13FB/b; the servo loop is again unbalanced and the trailing edge flaps actuator /X1 operates. The servo loop nulls nine seconds after the start of this final extension sequence; the trailing edge flaps are then fully extended and the TE FLAPS indicator pointer is at the landing (LDG) position.

19. If the FLAPS control lever is moved from TRAILING EDGE UP to LANDING, without pausing at TAKE OFF/APPROACH, the trailing edge flaps will require 15 seconds to fully extend.

Retraction of wing flaps

20. The circuit action of the trailing edge flaps positional servo loop during the retraction sequences is comparable to that during extension, but with reversal of polarity of the amplifier input and output voltages. Movement of the FLAPS control lever from LANDING to TAKE OFF/APPROACH causes relay /RL7 to be energized and, consequently, /RL8 to be de-energized. When contact set /RL8/4 breaks and /RL7/4 makes, the servo amplifier error signal input becomes negative, due to the

position of the wiper of /RV1a. The power amplifier output becomes positive and actuator motor /X1 operates, the direction of shaft rotation being opposite to that during extension sequences. The motor shaft rotates at a rate determined by the maximum voltage output of the servo amplifier, which is limited to +22V by the feedback limiting network /MR7, /R29, /R30 and /R32. Transistor /VT3 conducts and energizes the "TE retracting" relay, /T6/RL5, as soon as the servo amplifier output exceeds +5V.

21. Contact set /T6/RL5/1 operates a slave "TE retracting" relay, /T1/RL2, contact set No.1 of which operates in the hydraulic system, to discharge the capacitor that simulates the No.1 hydraulic system accumulator, in the event of hydraulic pressure failure. The auxiliary hydraulic pump is not selected automatically, however, during trailing edge flaps retraction sequences.

22. The trailing edge flaps retract to the take-off and approach (TO APP) position in nine seconds. If the control lever is then placed in the TRAILING EDGE UP position, /T3/RL6 energizes via /S3; operated contact set /T3/RL6/2 disconnects the holding circuit for /RL7, and released contact set /RL7/4 removes the remaining positive component of the error signal from the trailing edge flaps servo amplifier input. The TE flaps actuator operates until the wiper of the positional potentiometer /RV1a is at earth potential and the trailing edge flaps retraction sequence is completed. The time taken for the trailing edge flaps to retract from TO APP to TRAILING EDGE UP is six seconds, making a total trailing edge flaps retraction time of 15 seconds.

23. The leading edge flaps can now be retracted by setting the control lever to LEADING EDGE UP. Microswitch /S2 breaks when the control lever is moved away from LEADING EDGE DN, but /T3/RL5 ("LE down selected" relay) remains energized via /RL4/2 and /RL5/1 until the control lever is set to the LEADING EDGE UP position. Relay /RL4 operates when /S1 makes, and contact set /RL4/2 breaks the holding circuit for the coil of /RL5.

24. If LEADING EDGE UP is selected before the trailing edge flaps retraction sequence is completed, /RL5 is held energized via operated contact set /T1/RL2/2 ("TE flaps retracting" slave relay), thus ensuring that the leading edge flaps remain in the fully extended condition until the trailing edge flaps are fully retracted.

25. When /RL5 de-energizes, contact set /RL5/3 connects +50V to the input of the leading edge flaps integrating amplifier 13FB/a, the output of which then decreases from +100V to 0V in 7·5 seconds. The fully retracted condition of both leading edge and trailing edge wing flaps is then indicated.

Operation from the stand-by hydraulic system

26. In the event of the No.1 (normal) hydraulic system failure, the wing flaps can be powered from the No.2 (stand-by) hydraulic system, provided that the stand-by pressure is adequate. The HYD SYS selector switch AC/BT must then be set to STANDBY 2. This connects the +27V supply (para.7) to relay 13F/T3/RL3 (para.28) and, via /MR1, to microswitches /S3, /S4 and /S5 which initiate the trailing edge flaps functions; simultaneously, the supply from the leading edge flaps microswitches /S1 and /S2, is disconnected. Thus, the leading edge flaps cannot be operated by normal LEADING EDGE UP settings of the control lever when the stand-by hydraulic system is selected.

27. Relay /RL20 is energized via /MR2 and contact set 14G/T3/RL17/3 which is operated when the No.2 hydraulic pressure exceeds 1500 lb/in^2; thus, the indicators will "freeze" if the No.2 hydraulic pressure fails (para.8) and /RL20 is de-energized.

28. Operation of the HYD SYS selector switch to the STANDBY 2 position energizes relay 13F/T3/RL3, contact sets of which slave the operation of the leading edge flaps from the trailing edge flaps switch-settings.

29. When the FLAPS control lever is set to the TAKE OFF/APPROACH position, /RL5 is energized via operated contact set /RL3/4 and diode /MR22. Contact set /RL5/3 initiates the operation of the leading edge flaps integrator and, simultaneously, the trailing edge flaps actuator operates. Contact set /RL3/2 is also operated, and thus ensures that, under stand-by conditions, operation of the trailing edge flaps actuator is not delayed until the leading edge flaps are fully extended (para.12).

30. Operated contact set /RL3/1 energizes slave relay /RL9; operated contact sets /RL9/1 and /RL9/2 short-circuit resistors /R28 and /R29, respectively, in the feedback-limiting networks of servo amplifier 13FB/b. Thus when the flaps are operated from the stand-by hydraulic system, the output voltage of 13FB/b is limited to +15V and -18V, and the trailing edge flaps full extension and retraction times are correspondingly increased to 25 seconds. The operating times of the leading edge flaps remain the same as for normal operation.

31. When the FLAPS lever is set to the TRAILING EDGE UP position (for retraction), microswitch /S3 closes and /RL4 is energized, via operated contact set /RL3/3 and diode /MR23. Relay /RL5 is thus de-energized by contact set /RL4/2, and the output of the leading edge flaps integrator reduces to zero volts. Thus, the trailing edge and leading edge flaps begin to retract simultaneously.

32. When the wing flaps are operated from the stand-by hydraulic system, contact sets of the "TE flaps extending" slave relay /T1/RL1 and of the "TE flaps retracting" slave relay /T1/RL2 operate in the circuit of the simulated hydraulic system to

discharge the capacitor, that represents No.2 hydraulic system accumulator, in the event of hydraulic failure.

33. The gain of amplifier 13FB/b is preset by means of potentiometer 13AS/a/RV501 for the required Δ actuator motor speed.

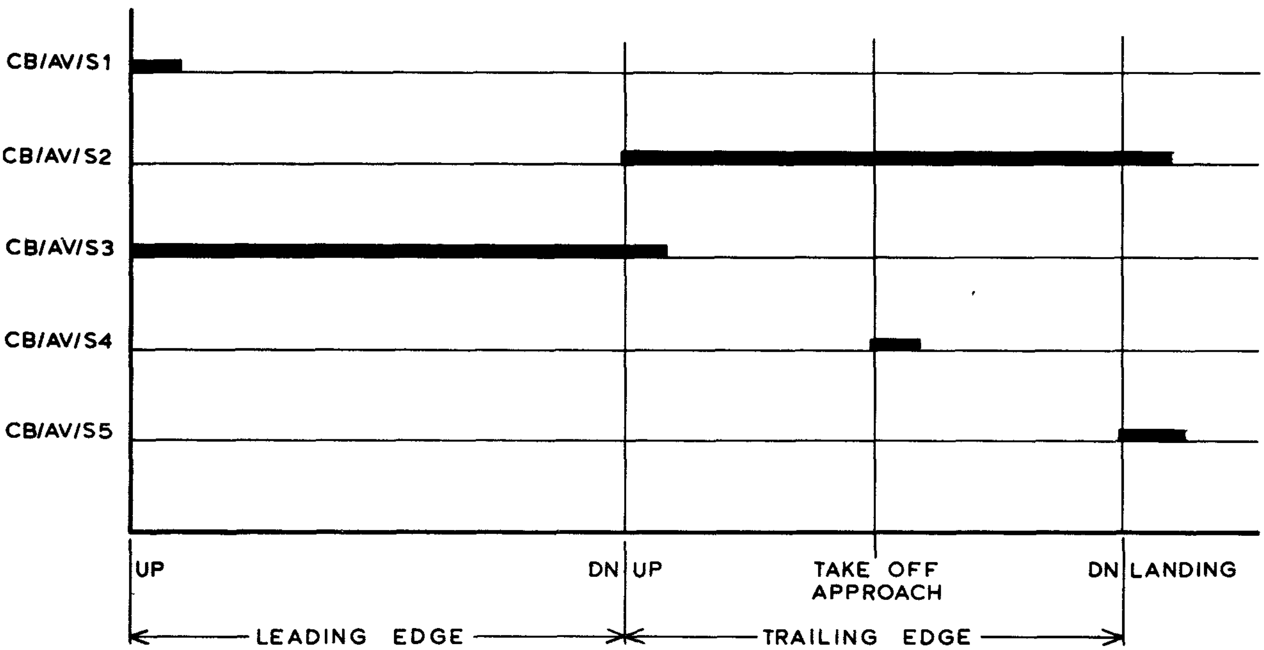


Fig.1 Flaps control lever switching sequence

Chapter 6

AIRBRAKES SYSTEMS

List of Contents

List of Illustrations

Introduction

1. The aircraft airbrake systems include the hydraulically-operated speed brake system and the braking dragchute system.

2. The aircraft speed brake consists of a petal-type airbrake that can be extended from the lower, rear fuselage surface. The jack which operates the speed brake is actuated from the "normal" (No.1) hydraulic supply. The jack can be either fully-extended or fully-retracted; the speed brake, therefore, has no intermediate positions and extends, or retracts, in 6·5 seconds.

3. The dragchute system is electro-mechanically operated. When the dragchute is released from its housing, it streams and provides a braking drag. Use of the dragchute is limited to 140 knots. When, during conditions of dragchute streaming, reverse thrust is selected, the dragchute collapses. Subsequent selection of forward thrust reverts the dragchute to the "streaming" condition. The dragchute is jettisoned (released) when no longer required.

4. In the simulator the drag- and pitching-effects due to the extended speed brake, or the streaming dragchute, are represented by the appropriate signals that are applied to the drag and pitch loop systems, respectively.

SPEED BRAKE CIRCUIT (/012)

5. Operation of the speed brake system depends on the availability of the No.1 hydraulic system and of the d.c. power supplied by the main d.c. busbar. The speed brake is controlled by the EXT SPEED BRAKE/off/RETR switch CB/AS, situated on the centre stand instrument panel. This three-position switch is spring-biased to the centre off position. A SPEED BRAKE EXTEND warning lamp, included on the annunciator warning panel (Part 9, Chap.5), lights when the speed brake is in any position other than fully retracted. In addition, this lamp flashes at a predetermined rate when the speed brake is not fully retracted, and extension of the landing gear has been selected.

6. The operating time required for full extension or retraction of the speed brake from the instant of selection (6·5 s) is obtained by the use of an integrating circuit that provides an airbrake (+A.B.) output; this +A.B. output varies from 0V to +100V during the extension or, from +100V to 0V during the retraction sequence. A relay is energized when the +A.B. signal attains a potential of +100V, simulating fully extended speed brake; a second relay de-energizes at 0V simulating a fully retracted speed brake The +A.B. signal is fed to the drag loop; a -A.B. signal, obtained by inverting the +A.B. signal via an inverter-amplifier, is fed to the pitch loop.

7. Failure of the speed brake system can be introduced by the flight instructor; when failed, the speed brake will remain in the position last selected. If the No.1 hydraulic system fails, the speed brake will remain retracted, or, if the failure of the hydraulic system occurs when the speed brake is extended, the speed brake will assume an intermediate position, but it will not retract fully.

Speed brake extension

8. When the speed brake switch CB/AS is set to the EXT position, the coil of the "speed brake extend or extending" relay 13F/T1/RL12 is energized from the main d.c.

busbar, via the normally-made pole of the SPEEDBRAKE fail switch XF/AC/S9 (mounted on the flight instructor's control panel), operated contact set 13F/T3/RL12/1 of the "hyd. available No.1" relay (Chap.2), the SPEED BRAKE NORM circuit breaker SL/49 and diode 13F/T2/MR6. Operated contact set /T1/RL12/1 ensures that the coil of /T1/RL12 is held in the energized state, via released contact set /T1/RL17/1, when the speed brake switch CB/AS is returned to its off position. Diode /MR6 prevents shorting of the +27V general supply to the main d.c. busbar via the self-hold circuit of relay /RL12.

9. Operated contact set /T1/RL12/2 connects the -50V supply to the input of integrating amplifier 13FA/a via resistor /T2/R2. When the amplifier output (+A.B.) becomes sufficiently positive, transistor /T2/TR1 conducts and the "speed brake not up" relay /T6/RL2 operates. The parallel-connected coils of "speed brake not up" slave relays /T1/RL4, and /RL16 are then energized from the +27V general supply via operated contact set /T6/RL2/1. Contact set /T1/RL4/1 operates in the hydraulic system (Chap.2) to simulate normal pressure demand of the airbrake system.

10. The +A.B. signal is fed via operated contact set /T1/RL16/3 and interconnection (2) to the drag loop system (Part 8, Chap.2) to represent increased drag due to the extending (or extended) speed brake. The +A.B. signal is also fed, via resistor /T2/R12, to the input of inverter-amplifier 13FA/b, which produces the -A.B. signal. Operated contact set /T1/RL16/4 connects the -A.B. signal, via interconnection (5), to the pitch loop system (Part 8, Chap.4), to represent the pitching moment due to the deflected speed brake.

11. Diode /T2/MR2 is disconnected from the integrating amplifier feedback loop by operated contact set /T1/RL16/2. The diode has no function until the amplifier output amplitude decreases to 0V (para.14). The output of the integrating amplifier increases from 0V to +100V in 6·5 seconds, this delay simulating the time required for speed brake extension. At the end of this delay, the +A.B. signal level is +100V, transistor /T2/TR2 conducts and energizes the "speed brake extended" relay /T6/RL3. Operated contact set /T6/RL3/1 supplies +27V to the coil of the "speed brake extended" slave relay /T1/RL3; the +A.B. signal at the output of amplifier 13FA/a is limited to +100V by diode /T2/MR1 connected in a negative feedback loop across the integrating amplifier via operated contact set /T1/RL3/1.

Speed brake retraction

12. When the speed brake switch CB/AS is set to the RETR position, the coil of the "speed brake retracting or retracted" relay /T1/RL17 is energized from the main d.c. busbar, via operated contact set /T3/RL12/1, the normally-made pole of the SPEED-BRAKE fail switch XF/AC/S9, the SPEED BRAKE RETRACT circuit breaker SL/50, and the A1 pole of switch CB/AS. Diode /T2/MR5 ensures that relay /T1/RL17 can be energized via either or both circuit breakers SL/49 and SL/50. Operated contact set

/T1/RL17/1 then breaks the holding circuit of relay /T1/RL12; released contact set /T1/RL12/3 and operated contact set /T1/RL17/3, provide a holding circuit for relay /T1/RL17.

13. Released contact set /T1/RL12/2 and operated contact set /T1/RL17/2 connect the +50V signal supply to the input of integrating amplifier 13FA/a via resistor /T2/R2; subsequently, the amplifier output is reduced from +100V towards 0V, transistor /T2/TR2 cuts off and the coil of relay /T6/RL3 is de-energized. Released contact set /T6/RL3/1 disconnects diode /T2/MR1 from the integrating amplifier feedback loop. The output of the integrating amplifier decreases from +100V to 0V in 6·5 seconds; this delay simulates the time required for the speed brake retraction. Transistor /T2/TR1 cuts off when the output of the integrating amplifier reaches 0V thus de-energizing the coil of /T6/RL2. The coils of the two slave relays (/T1/RL4 and /RL16) are also de-energized when contact set /T6/RL2/1 releases.

14. The output of integrating amplifier 13FA/a is maintained at 0V by diode /T2/MR2 which is connected across the amplifier, via released contact set /T1/RL16/2 (para.11). The +A.B. signal is disconnected from the drag loop system by released contact set /T1/RL16/3. Released contact set /T1/RL16/4 disconnects the -A.B. output of the inverting amplifier 13FA/b from the pitch loop system.

Warning lamp

15. When the speed brake is in any position other than fully-retracted, the SPEED BRAKE EXTEND lamp (on the annunciator warning panel, Part 9, Chap.5) is lit to provide warning of the speed brake position. The lamp circuit (interconnection (4)) is then earthed in the electrical system (interconnection (3)) via diode /T1/MR7, released contact set /T1/RL14/1 (para.17), operated contact set /T1/RL16/1 and the WARNING circuit breaker PJ/103. Circuit breaker PJ/103 also provides on connection to earth via interconnections (3) and (6) for the coil of "essential d.c. and warning lights circuit breaker intact" relay 14C/T26/RL16, included in the warning system (Part 9, Chap.5).

16. The steady light of the SPEED BRAKE EXTEND lamp changes to regular flashing, if, under airborne conditions, the speed brake is extended and the landing gear is selected down.

17. When the landing gear control lever is set to the LG DOWN position, switch AC/BQ (Chap.3) is made and +27V is connected via released contact set 13G/T3/RL11/1 of the "weight on wheels" relay (Chap.3), pole M of switch AC/BQ, resistor 13F/T2/R9, and released contact set /T1/RL14/2 to capacitor /T2/C2 which is connected in parallel with the coil of the "speed brake flasher" relay 13F/T1/RL14. Capacitor /T2/C2 charges at a rate determined by the resistive value of /T2/R9 and

the resistance of the coil of /RL14; when this charge reaches an adequate level, the coil of /RL14 is energized. Resistor /T2/R8 then provides a discharge path for capacitor /T2/C2, via operated contact set /T1/RL14/2. When /T2/C2 discharges sufficiently, /T1/RL14 releases and the sequence is repeated. The supply to the SPEED BRAKE EXTEND lamp is interrupted by the series-connected contact set /T1/RL14/1 (para.15), the interruption rate being twice per second.

Failure of the hydraulic system

18. When the speed brake is in the extended position, a failure of the No.1 hydraulic system causes the speed brake to be "blown-back" and to take up an intermediate position. In this condition the coil of the "speed brake blow-back" relay /T1/RL15 is energized from the +27V general supply via released contact set /T3/RL12/2 of the "hyd. available No.1" relay. Resistor /T2/R1 is connected in an additional negative feedback loop across integrating amplifier 13FA/a via operated contact set /T1/RL15/2, thus causing the +A.B. output to reduce exponentially due to the discharge rate of integrating capacitor /T2/C1; resistor /T2/R1 also reduces the gain of amplifier 13FA/a, and the +A.B. and -A.B. output signals are thus limited to approximately +25V and -25V, respectively. The "speed brake extended" relay /RL3 cannot, therefore, be operated, but the amplifier output is sufficient to operate the "speed brake not up" relay /RL2; thus the system simulates an intermediate position of the speed brake. If the hydraulic system is failed before the extension of the speed brake is selected, the output of amplifier 13FA/a is insufficient to energize relay /RL2 and the system remains in the "speed brake retracted" condition.

DRAGCHUTE CIRCUIT (/023)

19. Operation of the dragchute is controlled by means of the DRAG CHUTE control handle AC/AK situated on the centre main instrument panel. When the handle is pulled to the first stop, the "streaming" of the dragchute is simulated. When the handle is turned clockwise and pulled to the second stop, the dragchute is "released". The use of reverse thrust causes the dragchute to collapse.

20. The dragchute control handle actuates microswitch XC/AC/S1 which initiates the individual operating sequences of the dragchute circuit. The plunger of the microswitch is operated by cams on the control handle shaft, and the microswitch operation is such that, with the control handle in the off position (fully in), the common (c) pole of the microswitch makes with the normally open (n.o.) pole; when the control handle is operated to the first stop position (dragchute streaming), the common pole makes with the normally closed (n.c.) pole, and in the second stop position of the control handle the common pole again makes with the n.o. pole. Thus only two relays are required for the operation of the simulated dragchute system.

Dragchute streaming condition

21. When the dragchute control handle is pulled to the first stop position, the coil of "dragchute stream" relay, 14G/T26/RL12, is energized from the +27V general supply via the n.o. pole of the handle-operated microswitch XC/AC/S1, the n.c. pole of the instructor's RESET SYSTEMS switch XF/AM/S7 (para.25) and released contact set 14G/T26/RL10/1 (of the "dragchute release" relay, para.24). Operated contact set /T26/RL12/3, connected across the microswitch, provides a self-holding circuit for the coil of relay /T26/RL12.

22. The additional drag due to the extended dragchute is added to the total drag force by operated contact set /T26/RL12/2 in the drag loop system (Part 8, Chap.2).

Dragchute collapse

23. The dragchute collapses if reverse thrust is selected. This is achieved when at least one positive signal originating in the engine thrust system (Part 7, Chap.5) is applied via an OR-gate, formed by diodes 14G/T25/MR20 to /MR23, to the junction of /T26/RL12 and /T26/R12; the potential across the coil of relay /RL12 is thus equalized and the relay is released. Relay /RL12 is subsequently re-energized if the positive signals representing reverse thrust are disconnected, and the dragchute re-assumes the streaming condition.

Dragchute jettison

24. When the DRAG CHUTE control handle is set to the second stop position, the coil of the "dragchute release" relay /T26/RL10 is energized via switch XF/AM/S7 (para.25), microswitch XC/AC/S1 and operated contact set /T26/RL12/4. Operated contact set /RL10/2 completes the self-hold circuit of /RL10, and operated contact set /RL10/1 disconnects the holding circuit of relay /RL12. Thus the drag-correcting signal, due to the streaming dragchute, is disconnected by released contact set /RL12/2 (para.22) in the drag loop system.

Reset system

25. After each operation of the dragchute, the dragchute system must be reset by the flight instructor to simulate the refitting of the dragchute before each flight. The normally-closed RESET SYSTEMS switch XF/AM/S7 is fitted with an integral lamp XF/AM/S7LP that lights when either of relays /T26/RL12 or /RL10 is energized to indicate the use of the dragchute. The lamp also lights if the landing gear emergency release system has been selected and used (Chap.3) before a landing. In

all instances, the energizing voltage to the lamp is supplied via the RESET SYSTEMS switch and the relevant circuits which are provided with circuit-isolating diodes. The landing gear emergency release system is connected to the lamp and switch via interconnections (6) and (5) respectively. To reset the dragchute and/or the landing gear emergency release systems, the switch is operated, thus breaking any self-holding relay circuit and priming the systems before the next simulated flight training exercise.

Chapter 7

CABIN AIR CONDITIONING SYSTEM

List of Contents

List of Illustrations

Introduction

1. The cabin-pressurisation and air-conditioning system automatically controls the cabin air pressure and temperature. The cabin air conditions are displayed on four instruments that are mounted together with the pilots' manual controls on overhead panels RF and RJ.

2. The oxygen supply system is not simulated; the oxygen supply controls and indicators on the pilot's wainscot panels PE and PF are retained but are non-operational. The oxygen system includes a warning system that provides an audible and visual warning of low oxygen supplies. Provision is made for testing the warning devices.

CABIN AIR SYSTEM (/025)

3. The simulated cabin air system includes mechanical and electrical drives to the relevant indicators which can thus be directly controlled by the flight instructor.

The oxygen warning system is retained, but its operation is limited to procedural tests of the warning buzzer and lamp.

Cabin air instruments

4. The four instruments of the cabin air system are controlled directly by the flight instructor as follows:

(1) The CABIN pointer of the ALTITUDE indicator RJ/AC is actuated via Bowden cable from the instructor's CABIN ALTITUDE control XF/AJ/RV3.
(2) The FLIGHT pointer of the ALTITUDE indicator RJ/AC is actuated via Bowden cable from the instructor's FLIGHT ALTITUDE control XF/AJ/RV4.
(3) The pointer of the CABIN PRESSURE CONTROL is preset to register a normal cabin pressure reading, and the instrument is not provided with a drive.
(4) The cabin rate of CLIMB indicator is driven electrically, via circuit breaker PN/65, from the aircraft main d.c. busbar. The simulator CLIMB instrument RJ/AH consist of a centre-zero, moving-coil meter that is actuated by a control voltage from the instructor's CABIN R O C potentiometer XF/AJ/RV2. The positive wiper voltage of /RV2 provides deflection of the meter pointer above and below the centre-zero position due to the biasing network of XF/AJ/R11, /R12 and /R13; the meter indication is thus proportional to the setting of /RV2. The earthing of /RV2 and of meter RJ/AH (via PN/65) is made in the electrical system (Part 10, Chap.1) via a contact set which represents, when operated, energized main d.c. busbar.
(5) The CABIN TEMP. indicator RF/AC is driven electrically, via circuit breaker PN/67, from the main d.c. busbar. The simulator instrument consists of a moving-coil meter which is supplied with a control voltage from the instructor's CABIN TEMP potentiometer XF/AJ/RV1 via resistor /R14. The earthing of /RV1 and of meter RF/AC (via PN/67) is made in the electrical system (Part 10, Chap.1) via a contact set which represents, when operated, energized main d.c. busbar.

Oxygen warning system

5. The low oxygen warning buzzer PR/AB and warning lamp PE/AA/LP1 can be tested for correct function by the operation of a push-button OXYGEN WARNING TEST switch PG/AC, which is spring-biased to the "off" position. The warning buzzer may be silenced by operation of BUZZER SHUT OFF switch PG/AD.

6. Operation of the warning system relies on the availability of the main d.c. busbar supply. When the main d.c. busbar supply is available, the coil of relay

14G/T26/RL6 is energized via circuit breaker SL/48; operated contact set /RL6/1 completes the circuit for the buzzer, via released contact set /RL15/1. Operation of the OXYGEN WARNING TEST switch PG/AC completes the earth return for the buzzer. The warning lamp PE/AA/LP1 lights when the buzzer is energized.

7. Operation of the BUZZER SHUT OFF switch PG/AD energizes the coil of relay /RL15, which is then held energized via contact set /RL15/2. Operated contact set /RL15/1 open-circuits the energizing supply line to silence the buzzer. When test switch PG/AC is operated, only the warning lamp PE/AA/LP1 lights. To regain normal operation of the buzzer, the holding circuit of relay /RL15 must be disconnected; this is achieved by disengaging the OXYGEN WARNING circuit breaker SL/48, by failure of the main d.c. busbar supplies, or switching off the simulator.

8. The intensity of lamp PE/AA/LP1 is automatically reduced when the external navigational lights are switched on during simulated night conditions. When the EXTERIOR LIGHTS NAV POS switch, in the landing gear system (Part 10, Chap.3), is set to ON, the "dimming" relay 14G/T26/RL14 is operated, and resistor /T22/R9 is connected in the lamp circuit by operated contact set /RL14/1.

Blower motors

9. The blower motors of the cockpit air-conditioning system are energized via the FLT STA, SHUT OFF/NORMAL, switch RH/AG. In the simulator, these motors provide circulation of conditioned air in the cockpit via punkah louvres on pilot's and co-pilot's wainscot panels; the conditioned air is supplied from the room air-conditioning system via two inlets in the forward part of the fuselage; the two air outlets are positioned at the rear of the flight instructor's fuselage section.

Chapter 8

DE-ICING SYSTEM

List of Contents

List of Illustrations

Introduction

1. The effects of flight in icing conditions are simulated by operation of the flight instructor's ICE switch XF/AM/S8 (/022) which connects "icing" signals to the appropriate computer systems. These icing signals are increased progressively to represent the gradual formation of ice on the aircraft.

2. The simulated de-icing systems are selected by operation of the appropriate controls in the cockpit. When the controls are operated, the icing signals are reduced progressively to simulate gradual dispersal of the ice. The de-icing systems are controlled electrically and can be operated independently.

3. De-icing of the aircraft wings, tailplane and fin is achieved by alternate inflation and deflation of flexible "boots" fitted to the leading edges of these flying surfaces. The air pressure required for inflation of the boots is obtained from the engine bleed-air supply; partial vacuum for boot deflation is obtained from a Venturi

in the bleed-air pressure line. The boots system is operated by controls on the de-ice timer panel fitted to the cockpit right-hand wainscot in position SF/AA.

4. De-icing of the engine air intakes is accomplished by routeing the hot bleed-air supply to the intakes via control valves. The appropriate control switches and warning lamps are positioned on the pilot's main instrument panel AA.

5. The pitot heads for the flight instruments are protected from ice formation by electrical heaters which are controlled by switches contained on the co-pilot's side panel SA.

6. The electrically-heated windshields utilize a separate a.c. inverter supply which is integrated in the aircraft electrical supply and is described in Chap.1. The fuel heater de-icing system includes heat valves which are electrically controlled and their circuits are described in the fuel system (Part 7, Chap.2). The sensor vanes of the pre-stall warning system are electrically heated when the pre-stall warning is switched on; this circuit is included in the pre-stall warning shaker system described in the lift loop (Part 8, Chap.3).

ICE SWITCH FUNCTIONS (/022)

7. When the flight instructor's ICE switch XF/AM/S8 is operated, the "ice present" relay 14G/T23/RL14 is energized from the +27V supply, and relay 13E/T1/RL5 (/209), in the speed indicators system (Part 11, Chap.1), is also energized via interconnection (9); the following circuit conditions are then obtained:

(1) Contact set 14G/T23/RL14/1 connects +50V, via released contact set /T23/RL5/1 (of the "engine 1 antice on" relay, para.22), to the engine indicators systems (Part 7, Chap.6) to introduce the effects of engine air-intake icing which is indicated by reduced engine pressure ratio. Contact set /RL14/2 operates in the drag loop (Part 8, Chap.2), where it produces the effects of ice formation on the flying surfaces.

(2) Contact set 13E/T1/RL5/1 operates in the speed indicators system (Part 11, Chap.1) where it introduces the effect of icing on the pitot heads; consequently, the indicated airspeed is reduced.

(3) Contact sets 13E/T1/RL5/2 and /RL5/3 operate in the lift loop (Part 8, Chap.3), where, if the power supply to their anti-ice heaters is switched off, the simulated pre-stall warning sensor vanes are automatically failed.

DE-ICING SYSTEMS

8. Various combinations of icing and de-icing effects are possible due to the relative timing of the precautionary actions and the degree of introduced "icing".

Wing, tailplane and fin de-icing (/021 and /022)

9. The de-ice timer, SF/AA (/022), provides either automatic or manual control of the sequential inflation and deflation of groups of flexible boots; the boot groups are designated A, B, C, D and E and their disposition is shown, in a representative diagram, on the timer panel. The de-ice timer fitted in the simulator is an unmodified (aircraft) component.

10. The following controls and indicators are fitted on the de-ice timer panel:

(1) A LIGHT ICING/OFF/HEAVY ICING switch which provides selection of two rates of automatic operation of the de-icing boots. When the switch is set to one of the "on" positions, boot groups A, B, C and D are inflated for 6 seconds and group E for 3 seconds. With the switch in LIGHT ICING position the deflation period is 3 minutes, and when the HEAVY ICING switch-position is selected, the deflation time is reduced to one minute.

(2) Manual control of the operation of the boot groups is achieved by operating, at any given time, one of five push-buttons, each controlling one group of boots. Normally, the relevant boot groups are controlled manually when the LIGHT ICING/OFF/HEAVY ICING switch is set to OFF; however, any one of the push-buttons can be operated during automatic operation of the timer, with LIGHT ICING or HEAVY ICING selected, in which instance the automatic sequence is interrupted until all push-buttons are released.

(3) Five indicator lamps, marked A, B, C, D and E, that light when the respective boot group is inflated manually or automatically.

(4) A LOW SUCT WARN lamp that lights when the bleed-air supply to the boot groups is not available.

(5) A DE-ICER PRESS gauge that displays the pressure (from 0 to 35 PSI) of the bleed-air supply.

11. Sufficient bleed-air supply for the boot groups is obtained when the speed of at least one engine exceeds 40% indicated RPM, and the bleed-air shut-off valves are opened. This condition is represented by the parallel circuit of four N switch cards, e.g., 14BS/RV6 for engine No.1 (/021), which supply -27V to the "de-ice pressure

available" relay 14G/T26/RL2 via released contact sets of relays representing the shut-off valves (in the circuits of No. 1, 2 and 4 engines). The shut-off valves, e.g., contact set 14G/T21/RL9/2 for No. 1 engine, are controlled by switches contained on the overhead panel RH and are included in the circuit of the fire warning system (Chap. 9); the bleed-air supply must be shut off when overheating or fire is experienced in the various fire zones (e.g., /RL9 energized). The bleed-air supply from No. 3 engine is direct to the de-icing system to ensure that de-icing is available under emergency conditions. The circuit of "bleed-air off" relay /T26/RL1 is not utilized.

12. The -27V supply from the N switch cards (over 40% RPM) is also routed to relay 14G/T23/RL9 (/022), the contact set of which (para. 22) operates in the No. 1 engine de-icing system, and to the fuel filter heater circuits in the fuel system (Part 7, Chap. 2). Diodes, /T21/MR22 to /MR24, inclusive, isolate the individual engine de-icing and fuel filter circuits from the circuit of /RL2. Operated contact set /RL2/1 connects +27V to the coil of "delayed pressure" relay /T26/RL3 which is energized after a delay caused by the charging action of capacitor /T25/C2 via /T26/R3. The capacitor is discharged, via /T25/MR18 and /R6, when contact set /RL2/1 is released.

13. The pointer of the DE-ICER PRESS gauge, on the de-ice timer panel (para. 10), is driven by a synchro receiver. The rotor of synchro transmitter 14G/T4/TX1 is coupled to the shaft of uniselector 14G/T4/S1 (/021); the position of the uniselector wiper arm is determined by the setting of the instructor's DE-ICE PRESS switch XF/AL/S13 if the bleed-air supply is available (/RL2 energized, para. 11). When bleed-air is supplied from the engines, the uniselector will select a position corresponding to the required pressure set on the DE-ICE PRESS switch dial; conversely, when bleed-air is not available, the uniselector will return to its No. 1 position. The 24 switch-positions cover the range of 0-35 PSI of the DE-ICER PRESS gauge; the switch dial is calibrated in increments of 5.

14. The contacts of switch wafers /S13/1 and /S13/2 are arranged to give two "steps" of the uniselector for each switch position. Thus the 24 positions of /S13 correspond to 48 positions of the uniselector. The circuit of the switch is shown in the No. 1 position which corresponds to indicated 0 PSI. By advancing switch sections /S13/1 and /S13/2 to a selected pressure position, the uniselector "clockwise" motor 14G/T4/S1/2/50 is energized, via /S1/1 (up to and including the 25th position), or via /S1/2 (from the 26th to the 48th positions), the motor circuit being completed by operated contact set /RL2/2 and interrupter contacts /S1/2/dm. Suppressor network, /R1 and /C1, is connected across the interrupter contacts. With relay /RL2, and consequently /RL3, energized (para. 12), switch wafer /S13/3 provides the energizing voltage to the counter-clockwise motor /S1/1/50, via /S1/1/dm and operated contact set /RL3/1, if /S13 is returned to a lower PSI position.

15. If the de-ice pressure is not available (i.e., /RL2 and /RL3 de-energized), the counter-clockwise motor is energized with either positive or negative 27V supply from

uniselector sections /S1/5 and /S1/6, via released contact sets /RL2/3 and /RL3/2. The polarity of this 27V supply is negative if the indicated pressure is above indicated 10 PSI position, or positive if pressure below 10 PSI is indicated; the polarity change of the supply at 10 PSI is used for the low-pressure warning circuit of relay /T26/RL5 (para.17). In either instance the uniselector wipers will return to the indicated 0 PSI position. The suppressor network (/T4/R2, /C2a, /C2b and diodes /MR27, /MR28) is arranged to operate equally on positive or negative voltages.

16. Operated contact set /RL2/4, in the de-ice timer circuit (/022), disconnects the earth return of the LOW SUCT WARN lamp. This lamp is dimmed, when the external navigational lights are switched on, by resistor /T2/R5 which is connected in the lamp earth return by operated contact set /T23/RL16/1. The circuit of the "dimmer" relay /RL16 is in the landing gear system (Chap.3).

17. At pressures of less than 10 PSI, the de-ice pressure is insufficient for any de-icing action; this condition is simulated by contact sets of relay /T26/RL5 (/021); the coil of this relay is connected, via /MR19, to /S1/5 and /S1/6 (para.15). Operation of /RL5 is inhibited, by /MR19, for the first 14 positions of uniselector section /S1/5; when /S1/5 and /S1/6 are in any other position, the relay is energized from the negative supply. Contact set /RL5/1 is in the de-ice timer circuit (/022) and, when operated, connects the timer "press boots output" to the "de-ice timer on" relay /T24/RL1 via diodes /T2/MR1 to /MR5 and the circuit of transistor /TR1.

18. The operation and release of relay /T24/RL1 is delayed by the time constant of capacitor /T2/C1 and resistor /R2 in the base circuit of /TR1; this delay represents the transition time from deflation to full inflation of the flexible boots. Contact set /RL1/1 operates in the drag loop (Part 8, Chap.2), where it interrupts the icing signal at a rate determined by the frequency of the "press. boots output" from the de-ice timer.

19. The +27V supply to the de-ice timer is routed via contact set 13G/T5/RL19/2, ("de-ice power circuit breaker OK" relay) the operation of which is a function of faultable circuit breaker SL/58 (electrical system, Part 10, Chap.1). The 26V, 400c/s, supply to synchro transmitter /T4/TX1 is routed via contact set /T3/RL15/1 of the "main a.c. available" relay /RL15 which is operated when the No.1 main a.c. busbar is energized, via interconnection (7).

Engine de-icing (/022)

20. Progressive icing of the engine air intakes is indicated by a gradual reduction in the engine pressure ratio (EPR) indications on the respective P.R. gauges (para.7(1)). Operation of the ENG ANTI-ICING switches results in the P.R. gauge readings returning to normal, and an increase in the indicated engine exhaust gas temperature displayed on the EXH TEMP gauges.

21. The de-icing circuits of the four engines are similar except for component references; only the No.1 engine de-icing system is described.

22. When engine de-icing is selected, operation of the ENG ANTI-ICING switch AA/AM (for No.1 and No.4 engines) energizes the coil of relay 14G/T23/RL1 (redundant) and of the "engine 1 antice on" relay /T23/RL5 from the essential d.c. busbar supply, via the ENG ANTI-ICE PWR circuit breaker PN/80, released contact set /T21/RL9/1 ("bleed-air engine 1 shut off" relay) and contact set /T23/RL9/1 ("N_1 >40%" relay). Relay /T23/RL9 is energized from the wiper of N_1 switch card 14BS/RV6 (para.11); the coil of relay /T21/RL9 is included in the fire warning system (Chap.9).

23. Contact sets of relay /T23/RL5 perform the following circuit functions:

(1) /RL5/1, /RL5/2 and /RL5/3 operate in the engine indicators systems (Part 7, Chap.6); /RL5/1 (/022) disconnects the +50V icing signal (contact set /T23/RL14/1 operated) from the No.1 engine EPR circuit (via interconnection (2)), /RL5/2 connects a -50V signal to the No.1 engine exhaust gas temperature computing circuit to represent the hot bleed-air being supplied to the engine air intake, and contact set /RL5/3 operates in the EPR computing circuits to simulate the demand of hot bleed-air for the No.1 engine de-icing.

(2) /RL5/4 (/022) connects the earth return to the ENG. ANTI-ICING VALVE OPEN WHEN LIT lamp AA/AQ.

<u>Pitot heads de-icing</u> (/022)

24. When icing conditions are selected (para.7), progressive icing of the A.S.I. (airspeed indicator) and Machmeter pitot heads is indicated by a gradual reduction of indicated airspeed and Mach number. The reading displayed on the vertical speed indicators is not affected.

25. The pitot head anti-ice heaters are represented by relays 14G/T23/RL17, /RL18, /RL19 and /RL20. Operation of the PITOT HEAT switch SA/AN to the ON position energizes these four relays from the main d.c. busbar supply, via the four sections of switch SA/AN and the respective PITOT HEATERS circuit breakers SL/62, /63, /64 and /65.

26. Contact set /RL17/1 operates in the speed indicators system (Part 11, Chap.1) and removes the signal representing icing conditions from the Machmeter and A.S.I. circuits.

27. Series-connected contact sets /RL18/2 and /RL20/2 operate in the LOAD-meter circuit of the electrical system (Chap.1) and simulate the d.c. current demand for the pitot head heaters.

28. The contact sets of relay /RL19 are not used.

Chapter 9

FIRE WARNING SYSTEM

List of Contents

List of Illustrations

Introduction

1. The aircraft fire warning and control system provides detection, warning, and control of fires and overheating in the forward and aft compartments of the four jet engines. In the flight simulator, fires in the engine compartments can be simulated individually by switches operated by the instructor.

2. Warning of fire in the engine compartments is indicated by lamps fitted in the translucent handles of the four FIRE PULL controls on panel AC.

3. When the instructor simulates fire in the forward engine compartments, the respective warning lamps provide a steady illumination of the fire handles; fires selected in the aft compartments result in a regular flashing of the lamps.

4. The pilot can test the fire warning lamps, collectively, for correct operation by means of a fire warning test switch on panel AC. Four fail switches enable the instructor to fail, individually, the fire warning lamps.

5. The aft compartment OVERHEAT lamp AA/AB is wired for the press-to-test facility only, and does not provide any warning indication.

FIRE WARNING SYSTEM (/024)

6. Drawing /024 shows the part of the fire warning system that is related to No.1 engine, and the part which is common to all engines. All the engine warning systems are similar; therefore, only the No.1 engine circuit and the circuit common to all engines are described.

7. The energizing supply for the No.1 engine warning lamps, contained in the handle of the FIRE 1 PULL control AC/AM, is routed via contact set 14F/T2/RL20/2, (operated when the essential d.c. busbar supply is available), NAC 1 circuit breaker PP/41, the 'on' poles of the flight instructors' FAIL FIRE WARNING switch XF/AD/S9, and parallel-connected contact sets 14G/T21/RL1/1 and /RL5/2.

8. The coils of relays /RL1 and /RL5 each have two energizing paths, one via the FIRE ZONE 1 and FIRE ZONE 2 instructor's switches XF/AD/S7 and /S8 respectively, the other path via the FIRE DET WARNING LIGHT TEST switch AC/AF. The energizing supply routed via the instructor's switches is from the +27V general supply. The pilot's test switch AC/AF is connected to the essential d.c. busbar supply, via TEST circuit breaker PP/45, to simulate the dependability on the aircraft electrical supplies.

9. Diodes 14G/T22/MR1 and /MR5 prevent the +27V line being shorted to the essential d.c. busbar supply if the test switch AC/AF and the instructor's switches are operated simultaneously.

10. Relay /RL5 is connected in a flasher circuit; when the test switch AC/AF is set to the AFT ZONE position, or the instructor's switch XF/AD/S7 is operated, capacitor /C1, connected in parallel with the coil of relay /RL5, charges at a rate determined by the resistive value of /R1 and the coil of /RL5. When this charge reaches the relay operating potential, (after approximately 0·5 of a second), the coil of relay /RL5 becomes energized. Resistor /R5 then provides a discharge path for capacitor /C1, via operated contact set /RL5/1. When capacitor /C1 discharges sufficiently, /RL5 releases and the sequence is repeated. The supply to the warning lamps is thus interrupted by contact set /RL5/2 at a frequency of approximately 100 times per minute.

Fire extinguishing

11. Operation of the FIRE 1 PULL control AC/AM results in the following effects:

(1) The (C) contacts of microswitch AC/AM make and connect the essential d.c. busbar supply to the coil of relay /RL9 via the BLEED AIR SHUT OFF circuit breaker PK/89 and contact set /RL14/1.
(2) Contact set /RL9/1 operates in the de-icing system (Part 10, Chap. 8), and disconnects the No. 1 engine anti-ice system.
(3) Contact set /RL9/2 operates in the de-icing system and shuts off the No. 1 engine simulated bleed air valve.
(4) The LOW SUCT WARN lamp (in the de-icing system) on the de-ice panel SF lights, being connected by the action of /RL9/2 to earth.
(5) The (B) contacts of microswitch AC/AM operate in the fuel system (Part 7, Chap. 2), and shut off the simulated No. 1 engine fuel supply.

12. The circuit conditions after operation of the 2, 3 and 4 FIRE PULL controls AC/AN, /AP and /AQ respectively, are similar to those described for the FIRE 1 PULL control AC/AM except for the following:

(1) When FIRE 2 PULL control is operated, the (A) contacts of microswitch AC/AN operate in the hydraulic system (Part 10, Chap. 2), and:

(a) shut off the simulated No. 1 hydraulic supply
(b) disconnect the No. 2 engine ignitor, in the engine starting system (Part 7, Chap. 3), thus inhibiting subsequent starting of the No. 2 engine.

(2) When the FIRE 3 PULL control is pulled, the (A) contacts of microswitch AC/AP operate in the hydraulic system (Part 10, Chap. 2), and:

(a) shut off the simulated No. 2 hydraulic supply
(b) disconnect the No. 3 engine ignitor, in the engine starting system, thus inhibiting subsequent starting of the No. 3 engine.

The No. 2 contact set of "bleed air engine 3 shut off" relay /RL12 is not used in the de-icing system; the bleed air supply from the No. 3 engine is fed directly to the aircraft de-icing system. Thus, when the FIRE 3 PULL control is operated, the LOW SUCT WARN lamp on panel SF cannot light.

(3) When the FIRE 4 PULL control is pulled the circuit conditions are as described in para. 11(1) to (5).

Bleed air control

13. Four BLEED AIR switches RH/AC, /AD, /AE and /AF control the bleed air valves of the four engines. When the BLEED AIR ENG 1 switch RH/AC is set to the SHUT OFF position, relay /RL9 is operated and the conditions are as described in para. 11(1), (2), (3) and (4).

14. Operation of the BLEED AIR switches for engines 2 and 4 is similar to that described for the No. 1 engine BLEED AIR switch. Operation of the No. 3 engine BLEED AIR switch RH/AE is as described in para. 11(1) and (2).

15. The EMER PRESS SYSTEM switch RJ/AD, when operated, routes the essential d.c. busbar supply via EMER PRESS circuit breaker PP/62 to the coil of relay /RL14; operated contact sets /RL14/1, /2, /3 and /4 connect the coils of relays /RL9, /RL10, RL12 and RL13 in parallel with the coil of /RL14. The bleed air valves for each engine are thus shut off and the circuit conditions are as described in para. 11(1), (2), (3) and (4) for each engine, except for No. 3 engine which, if running at speeds in excess of 40% indicated, continues to supply bleed air to the aircraft de-ice system.

Chapter 10

COCKPIT LIGHTING

List of Contents

List of Illustrations

Introduction

1. The lamps, lamp fittings, and lamp controls in the simulator cockpit are similar to those fitted in the aircraft. The +27V d.c. and 115V, 400c/s, supplies to the lamps are fed via contact sets of heavy-duty relays that are energized when the main and essential d.c. busbars are energized.

2. The appropriate aircraft circuit breakers are connected in the supplies to the heavy-duty relay and lamp circuits which are shown on drawings /026 to /030 inclusive. Contact sets of relays, representing the aircraft energized busbars, are connected in the power lines to the control switches, thus making the lamp circuits dependent on the appropriate aircraft electrical supplies.

SIMULATOR LAMPS CIRCUITS

Pilot's panel lighting (/026)

3. The +27V d.c. and 115V, 400c/s, supplies to the lamps situated on the pilot's instrument- and circuit breaker-panels are controlled by two "on-off" dimmer switches PM/AL and PM/AK, that are mounted on the cockpit left-hand wainscot lamps control panel PM.

4. The LEFT INST PANEL LTS control, PM/AL, consists of a rotary switch that is connected to multiple tappings on the secondary winding of an adjacent transformer. Rotation of control PM/AL provides progressive dimming of the lamps.

5. The selected 400c/s output from control PM/AL is fed to the pilot's flight instrument panels via fuses PM/AQ and /AP; both fuses, rated at 6·25A, are mounted on the lamps control panel. The LEFT CONSOLE & VERT PANEL switch PM/AK has three positions, DIM, OFF, and BRT. When switch /AK is in the BRT position, +27V is fed directly to the lamps on the pilot's circuit breaker panels; in the DIM position, a 6-ohm resistor is connected in the supply and the current to the lamps is reduced.

6. Panel lamp PM/AD, mounted on the left-hand wainscot, is energized via inter-connection (1) from the overhead floodlight switch RB/AE (para. 9).

Co-pilot's panel lighting (/027)

7. The co-pilot's panel lighting is similar to the pilot's panel lighting described in para. 3 to 6 inclusive, except for component references.

Overhead and instrument lighting (/028 and /029)

8. The lamps on the pedestal and on the centre instrument panels are controlled by the ENGINE, FUEL PANEL & CENTRE STAND INSTRUMENT LIGHTS switch RB/AG (/028), mounted on the right-hand overhead lighting control panel. In the OFF position, +27V is routed via the switch contacts to the warning system (Part 9, Chap. 5), to prevent dimming of the annunciator lamps when the centre instrument panel lamps are extinguished (in daylight conditions). Switch RB/AG provides six positions of lamp dimming, via series resistors; the seventh position connects the +27V directly to the lamps.

9. The FLT STA switch RB/AE controls the overhead red/white floodlights and the lamps situated on the glare-shield panel. The switch has three positions WHITE, OFF and RED. When set to the WHITE position, +27V supply is connected to the glare-

shield lamps, to the white overhead floodlights /LP2 and to lamps PM/AD (para.6) and SK/AD, mounted on the left-hand and right-hand wainscot respectively. When set to the RED position, only the red overhead floodlights /LP1 are lit.

10. When the engine starter is operated during the engine starting sequence (engine starting system, Part 7, Chap.3), the floodlights and the glare-shield lamps extinguish; this function is performed by contact sets of relays controlled from the engine starting circuit. When the "ignition busbar control" relay 14C/T1/RL7 and the "ignition busbar transfer" relay /RL8 are operated in the engine starting system, operated contact set /RL8/1 de-energizes the coil of slave relay 13G/T3/RL12, and operated contact set /RL7/3 changes over and connects the lamps of the centre instrument panel AC to switch RB/AG via contact set 13G/T3/RL10/1; the operated heavy-duty contact set 13G/T3/RL12/1 then disconnects the supply to the floodlights and to the glare-shield lamps.

11. The OVHD INST LTS switch RB/AF controls the lamps situated on the overhead instrument panels as detailed on drawing /029; the switch has three positions BRT, OFF AND DIM, and its two sections are connected in parallel to increase the current rating. In the DIM position a wirewound resistor RB/R1 is connected in series with the supply. Resistor RB/R1 is of the preset type, but being mounted behind the panel, it is not normally accessible.

<u>Simulator lighting</u> (/030)

12. Drawing /030 shows the circuit of the flight instructor's panel-illuminating lamps and of the service lamps fitted in the flight instructor's fuselage section and on the base frame of the simulator motion installation.

13. Two tubular lamps are mounted above the instructor's station for illumination of the control panels; the lamps are switched on and off by PANEL LIGHTS switch XF/AH/S8, and their brightness is controlled by means of the PANEL LIGHTS Variac XF/AH/T1.

14. The fuselage internal service lamp and its mains on/off switch are mounted in the bottom left-hand corner of the instructor's station, below the faults panels.

15. The external service lamp and its adjacent on/off switch are mounted on the inside of the rear part of the rectangular base structure.

Chapter 11

NOISE SYSTEM

List of Contents

List of Illustrations

General

1. The flight simulator is provided with a noise system which reproduces the various aircraft and engine noises during simulated flying or groundborne conditions. Aircraft noises consist of aircraft profile air flow noise, individual engine noises, i.e., compressor, turbine and exhaust, and noises produced when the undercarriage is raised or lowered and when the aircraft is landing and taxying. The level of the airflow noises is dependent on the aircraft speed. Engine noises increase proportionally, in amplitude and pitch, with engine speed.

NOISE SYSTEM (/110)

2. The noise system generates, electronically, the following noises:

(1) Aircraft profile air noise
(2) Undercarriage profile air noise
(3) Taxi rumble
(4) Turbine whine
(5) Jet roar.

The noises originate in the common air noise unit (Part 5); the outputs of this unit are applied to four identical engine noise units (Part 5) which are capable of producing the turbine start noise, turbine whine noises and propeller noise.

Note...

In the noise system of this aircraft simulator, the turbine start noise and propeller noise are not used.

The component noises are mixed and supplied as one output, per engine, to the aircraft noise mixer unit (Part 5). Two mixer units are used in the noise system; each mixes the output of a pair of engine noise units, and provides a drive to one of the two loudspeaker units (Part 5).

3. The pitch, amplitude and timing of the noises is accomplished by d.c.-voltage bias variations from the appropriate engine speed (N) potentiometers, dynamic pressure (q) potentiometers and contact sets of relays; these controls are driven by the respective flight and engine simulator systems, and together with the individual noise units constitute the noise system.

4. The noise system is switched on by the instructor's master NOISE switch XF/AH/S4. When the switch is made, the simulator -27V supply is fed, via PL1/13, to the air noise unit in which a -20V stabilized supply line is produced and fed, via PL1/7, to the four engine units and to the two mixer units. The -27V supply is switched by internal contact sets in the air noise unit when at least one of four contact sets (14F/T1/RL8/3, /T2/RL8/3, /T3/RL8/3 and /T4/RL8/3) is operated and thereby energizes the coil of a relay. The coils of the four relays are energized when the HP cocks are opened and the engine speed of the respective engine reaches or exceeds 8·25% (fuel system, Part 7, Chap.2); the -27V supply is then connected, via PL1/6, to No. 1 loudspeaker unit XE/AA, and, via PL1/8, to No. 2 loudspeaker unit. The loudspeaker amplifiers are, therefore, switched off unless at least one engine speed is in excess of 8·25%, thus preventing any spurious noises from the loudspeakers.

Air noise unit and controls

5. The aircraft profile air noise output of the air noise unit, via PL1/16, includes the undercarriage profile air noise signal and the taxi rumble signal. The level of the aircraft profile air noise signal is controlled by q potentiometer 13DS/RV19, via PL1/22, which causes an increase in signal amplitude as the aircraft airspeed is increased. The undercarriage profile noise signal is similarly controlled by q potentiometer 13DS/RV18 connected to the unit via PL1/3. The presence of the undercarriage profile air noise signal depends on the availability of the +27V relay-energizing voltage via PL1/2. This supply is controlled by a relay in the landing gear system (Part 10, Chap.3), and the supply is available when the nosewheel is extended. The undercarriage taxi rumble signal is controlled by contact set

13A/T1/RL5/4 which is made on touchdown (height and touchdown system, Part 8, Chap.7) and provides the +27V supply to the air noise unit "touchdown" slave relay via PL1/1. The taxi rumble noise is also fed, via interconnection (2), to the motion drive system (Part 4, Chap.2).

6. The jet roar output of the air noise unit is supplied, via PL1/18, at a fixed amplitude to the engine noise units, in which the signal is made proportional to the respective engine speed N (para.9).

7. The turbine noise output of the air noise unit, via PL1/20, consists of a 20kc/s sinewave signal which is mixed with a variable-frequency oscillator output in the engine noise units (para.10) to provide the turbine whine signal.

Engine noise unit and controls

8. The circuits of the four engine noise units are identical and only No.1 engine unit (XH/AK) is described. The noise-signal outputs of the air noise unit are supplied in parallel to all four engine noise units.

9. The aircraft and undercarriage profile air noise signals and the taxi rumble signal are fed to the engine noise unit via PL1/12 for mixing with the engine noise signals. The amplitude of the jet roar signal, via PL1/20, is controlled by q potentiometer 13DS/RV17 which supplies all four engine noise units via PL1/22. The shape of the q potentiometer is such that the jet roar signal is faded out as the forward airspeed increases. A second control over the amplitude of the jet roar signal is provided by N_1 potentiometer 14BS/RV9, via PL1/5, which increases the jet roar with increased engine speed N.

10. The turbine noise input, via PL1/3, consists of a 20kc/s sinewave signal which is mixed with a variable-frequency output (20 to 25kc/s) of an internal sawtooth generator. The frequency of the sawtooth generator is given by the position of the wiper of N_1 potentiometer 14BS/RV10 which causes a higher pitch turbine noise signal to be produced at higher No.1 engine speed. The amplitude of the mixed turbine whine signal is proportional to the biasing voltage from N_1 potentiometer 14BS/RV9 which also controls the jet roar signal amplitude (para.9).

Signal mixing and audio output

11. The mixed output of all aircraft and No.1 engine noise signals is fed, via PL1/2, to section 1 of the aircraft noise mixer unit (XH/APa) for mixing with the output of the No.2 engine noise unit. The combined output of the mixer unit feeds the No.1 loudspeaker unit XE/AA.

12. The loudspeaker unit (Part 5, Chap. 8D) contains a phase-splitting stage and a class B push-pull output stage which drives a loudspeaker. The audio stages are capable of reproducing the wide range of audio frequencies produced in the noise system.

PART 11

FLIGHT INSTRUMENTS

Chapter 1

SPEED INDICATORS

List of Contents

List of Illustrations

Introduction

1. The simulator airspeed indicators (A.S.I.) consist of electrically-driven instruments which are housed in aircraft-type instrument containers; the airspeed indicators are fitted on the pilot's and co-pilot's main instrument panels in the cockpit, and on the radio aids instructor's GCA panel (rack 22). Each instrument has one pointer and a drum displaying the airspeed and another (striped) pointer indicating the maximum permissible airspeed (para.3). The airspeed and maximum airspeed pointers give readings on the usual circular scale which is calibrated from 50 to 650 KNOTS and which is marked at intervals of 10 knots; the airspeed drum reads the "tens" and "units", which are related to the airspeed pointer, on a rotary scale marked at 2-knot intervals. The airspeed pointer and drum counter are actuated by a motor, the maximum airspeed pointer being driven by the rotor of a synchro-receiver.

2. The airspeed drive signals are computed from the relevant flight computer signals which are summed at the input of the motor-drive amplifier of the co-pilot's airspeed indicator. The airspeed indicator pointer and drum are driven, via a reduction gear, by a positional-servo motor; the positional, rotary, potentiometer is also coupled to the motor-gear assembly. The positional signal of the co-pilot's servo circuit provides the drives for the other two slave instruments and for the over-speed warning system (para.4). When aircraft icing conditions are simulated, an additional input is connected to the motor-drive amplifier input to reduce the readings of the three airspeed indicators. In addition, the operation of the airspeed pointer of the pilot's A.S.I. can be failed by the flight instructor.

3. The maximum airspeed drive signal is computed separately as a function of height Z. The amplified signal drives an actuator which positions a synchro-transmitter. The synchro-receivers are fitted in the three respective A.S.I. instrument containers and their rotors are coupled to the striped pointers.

4. The airspeed indicators system includes an over-speed warning bell which sounds when the airspeed exceeds 368 ± 5kt. indicated. The over-speed warning signal is obtained by comparison of the airspeed indicator signal with a fixed bias voltage.

5. The Machmeter consists of a moving-coil meter driven by an amplifier at the input of which the appropriate flight computer signals are summed. The effects of the Machmeter pitot head icing are simulated by an additional switched input signal which reduces the Machmeter readings, when icing is selected by the instructor.

AIRSPEED INDICATOR CIRCUITS

Co-pilot's airspeed indicator (/210)

6. The simulator A.S.I. circuits are controlled by the V_T signal, supplied from the drag loop (Part 8, Chap.2), which is corrected for height Z, Mach number M and aircraft weight W. The outputs of the appropriate potentiometers are summed and compared with the output of the positional, servo-driven potentiometer. The amplified difference-signal drives the instrument motor which is coupled via a reduction-gear to the instrument pointer and drum. The sum of the A.S.I. component signals is computed according to the following design equation:

$$\text{A.S.I.} = 0{\cdot}601\ f_5(Z)\ V_T + f\left[30\ f_{11}(M)\ f_9(Z)\right] + 310\ \frac{q}{W} + \text{ICING}$$

where $f\left[30\ f_{11}(M)\ f_9(Z)\right]$ is a non-linear function of the MZ product.

7. The following signals are summed at the input of the co-pilot's A.S.I. servo-drive amplifier 13EE:

(1) A signal corresponding to the first term of the equation; this signal is obtained from the wiper of Z potentiometer 13AS/RV5 which is fed with the $-V_T$ signal from the drag loop (Part 8, Chap.2); the resulting signal thus includes the effect of height (or air density) on the indicated airspeed. The minimum reading of the airspeed indicators can be adjusted by preset potentiometer 13E/T3/RV14 which, together with /R42, provides a fixed bias at the minimum $-V_T$ signal from 13AS/RV5. Diodes 13E/T3/MR6 and /MR7 isolate the two negative voltage sources. The maximum, negative signal voltage, present at the junction of scaling resistors 13E/T5/R3a and /R3b, is limited to -50V by diode /T3/MR8.

(2) The 30 f_{11}(M) f_9(Z) signal which corresponds to the second term of the equation; the non-linear function (f) of the term simulates the positional error included in the readings of the airspeed indicators. This error is due to the pitot head position and mounting. The product of 30 f_{11}(M) f_9(Z) is a negative voltage from Z potentiometer 13AS/RV9 which is fed with the M signal from potentiometer 13CS/RV11. The positional error signal is supplied from potential-divider network 13E/T5/R4 and /R6, via /R7 and diode /MR1, to the junction of scaling resistors /R9 and /R8. At small negative values of the 30 f_{11}(M) f_9(Z) signal, diode /MR1 conducts and the (f) corrected signal is fed to the amplifier input via 13E/T5/R8.

(3) A signal corresponding to 310 $\frac{q}{W}$ is obtained from W potentiometer XF/AA/RV2f which is controlled by the instructor, and which is fed with the -q signal originating in the drag loop (Part 8, Chap.2); the resulting signal is reduced in amplitude by potential-divider consisting of 13E/T5/R10 and /R12.

(4) The "icing" signal which is supplied, via interconnection (6), from the Machmeter icing-signal control-circuits (para.22) when the instructor selects icing conditions by operation of the ICE switch XF/AM/S8 (de-icing system, Part 10, Chap.8). When icing is selected, capacitor 13E/T5/C1 is charged with a positive voltage via resistors /R17 and 14G/T23/R21 (on /209), with a time constant of approximately 5·5 minutes, thus simulating progressive icing of the pitot heads; consequently, the (positive) icing signal, supplied to amplifier 13EE, reduces the reading of the airspeed indicators. When the pitot head heaters are switched on, or when the instructor removes the icing conditions, capacitor /C1 discharges, and the airspeed indicators revert to normal readings.

(5) The positive signal from the positional-feedback potentiometer AC/BS/RV1; in the absence of other signals (i.e., aircraft stationary), this positional signal

is balanced against the negative minimum airspeed signal supplied via resistor 13E/T5/R3b (sub-para. (1)). Potentiometer AC/BS/RV1 also supplies the drive signal for the pilot's and instructor's airspeed indicators (para.9), to the over-speed warning circuit (para.18) and to the icing-signal control-circuits of the Machmeter (para.22).

8. The output of amplifier 13EE provides the drive for motor AC/BS of the co-pilot's airspeed indicator. The motor drives the airspeed pointer and drum via a reduction gear. The amplifier gain is preset by potentiometer 13E/T5/RV2.

9. The co-pilot's A.S.I. circuit provides the drives for the pilot's and radio console instructor's airspeed indicator from the wiper of the positional potentiometer AC/BS/RV1 (para.7(5)); this ensures that the airspeed indications of all three instruments are synchronized.

Pilot's and instructor's airspeed indicators (/210)

10. The circuits of the pilot's and radio aids instructor's A.S.I. are similar, both being driven by a common signal which originates from potentiometer AC/BS/RV1 (para.9).

11. Amplifier 13EC provides the drive for the pilot's airspeed indicator motor AA/AD; the amplifier is fed with the summed positive output of potentiometer AC/BS/RV1 and negative output of positional potentiometer AA/AD/RV1. The polarity and amplitude of the difference signal establishes the speed and direction of rotation of motor AA/AD. The gain of amplifier 13EC is preset by feedback potentiometer 13E/T5/RV22.

12. The flight instructor is provided with the ASI 1 fail switch XF/AK/S10, the operation of which breaks the circuit of the pilot's A.S.I. motor AA/AD; the motor is thus stopped and the airspeed pointer and drum remain stationary.

13. The radio console instructor's airspeed indicator 22AF/M1 is similar in circuit configuration and operation to the pilot's instrument. Failure of the instrument is, however, not simulated.

Maximum airspeed indicators (/217)

14. The maximum permissible airspeed is displayed by a striped pointer on each A.S.I. gauge; these pointers are driven by a synchro system which is actuated by a positional-servo. The pointer deflection is a function of aircraft height Z and the corresponding signal is computed according to the following equation:

$$V_{NE} = 368\, f_{21}(Z) \quad (NE = \text{never exceed})$$

15. The circuit of the maximum airspeed indicator consists of summing amplifier 13EG/a which drives, via a power amplifier, actuator motor 14AS/d/X1. The motor speed and direction of rotation depend on the signal difference between the outputs of Z potentiometer 13ES/RV21 and of positional potentiometer 14AS/d/RV1. The gain of the motor-driving loop is preset by 14AS/d/RV501. The computed maximum airspeed is registered as a shaft position of motor /X1, this shaft being coupled to /RV1 and rotors 14AS/d/TX1 and /TX2 of the synchro system. Synchro-transmitter /TX1 drives the synchro-receiver system of the pilot's airspeed indicator (AA/AD); the synchro-receivers of the co-pilot's and instructor's instruments (AC/BS and 22AF/M1 respectively) are wired in parallel and are driven by /TX2.

Over-speed warning system (/217)

16. When the aircraft reaches a speed of 368 $\pm$ 5kt., a warning bell rings. The bell is operated from the main d.c. busbar, via a circuit breaker and a contact set of the airspeed warning relay-switch. A separate test switch is provided for testing the bell operation.

17. The simulator over-speed warning circuit determines the warning-airspeed by comparison of the A.S.I. drive signal with a fixed bias voltage. At 368kt. indicated, a relay coil is energized and the warning bell is actuated via the contact set of a slave relay.

18. The speed discriminator consists of the circuit of amplifier 13EG/b which is fed with the sum of the positive airspeed-indicator drive signal from potentiometer AC/BS/RV1 (para.7(5)) and a fixed negative signal supplied from the -50V line via resistors 13E/T6/R6 (short circuited by released contact set /T1/RL6/1) and /R5. At speeds of less than 368kt., the summed signal is negative and the coil of the "overspeed warning switch made" relay 13E/T1/R6, at the output of amplifier 13EG/b, cannot be energized due to the reverse-biased diode 13E/T6/MR2; the amplifier gain is established by negative-feedback resistor 13E/T6/R1. When the positive A.S.I. signal overcomes the negative bias, the negative output of the amplifier energizes the coil of /T1/RL6; simultaneously, the feedback resistor /R1 is virtually earthed via conducting diode /MR2 and the amplifier gain is increased considerably to achieve positive operation of relay /RL6. If the airspeed and the corresponding signal is increased further, a second negative feedback path, via diode /MR1 and resistor /R3, limits the amplifier output signal and thus ensures that the relay-operating voltage is kept fairly constant. When relay /RL6 operates, scaling resistor /R6 is connected in series with /R5; consequently when the airspeed is reduced below the over-speed limit, the release of relay /RL6 is delayed until a safe speed margin, below the limit, is obtained.

19. The "over-speed warning" bell, PR/AA, is energized by heavy-duty contact set 13E/T1/RL20/1 when contact set /RL6/2 is operated and the coil of slave-relay /RL20 is energized. The energizing voltage for /RL20 is routed via the normally-made (operated) contact set 13E/T1/RL4/2 representing the "main d.c. busbar energized" condition. Circuit breaker SL/43 completes the circuit of the bell solenoid.

20. Provided that the aircraft electrical supplies are available, the warning bell can be tested by operation of OVERSPEED WARNING TEST switch, SA/AV, to the TEST position. The switch is wired in parallel with contact set 13E/T1/RL6/2 (para. 19).

MACHMETER CIRCUIT (/209)

21. The Mach number is indicated on the Machmeter fitted in position AC/AD. The simulator Machmeter consists of a moving-coil meter which is driven by a type DH amplifier, 13EB/a; the amplifier input signals correspond to the terms of the following equation:

$$M_I = M + 7{\cdot}416 \times 10^{-8} \; V_T \; q \; f_{20}(Z) - 0{\cdot}253 - \text{ICING}$$

where $M = 0{\cdot}001034 \; V_T \; f_2(Z) \; f_{4a}(\delta_T)$

22. The M term, which is computed in the drag loop (Part 8, Chap. 2), is fed via interconnection (2) and scaling resistor 13E/T3/R3 to the input of the summing amplifier 13EB/a. The second term of the equation corresponds to the signal obtained at the wiper of q potentiometer 13DS/RV15 which is supplied with $V_T \; f_{20}(Z)$ from Z potentiometer 13AS/RV20. The signal corresponding to constant -0·253 is a fixed amplitude potential supplied via 13E/T3/R4. When icing conditions are simulated by the instructor, relay coil /RL5 is energized via the ICE switch XF/AM/S8 (de-icing system, Part 10, Chap. 8), and the "icing" signal is switched on by operated contact set 13E/T1/RL5/1 provided that the Machmeter pitot heater is not switched on (released contact set 14G/T23/RL17/1). When icing is selected, the positive A.S.I. signal from potentiometer AC/BS/RV1 (para. 7(5)) is fed to the delay network of capacitor 13E/T3/C1 and resistors /R8, and to a similar delay circuit of the A.S.I. system (para. 7(4)). Capacitor /C1 is charged, via 13E/T3/R8 and 14G/T23/R21, with a time constant of approximately 10 minutes to simulate progressive icing of the Machmeter pitot head; the Machmeter reading is, consequently, reduced. When the pitot head heaters are switched on (contact set 14G/T23/RL17/1 operated), or when the instructor removes the icing conditions (contact set 13E/T1/RL5/1 released), capacitor /C1 discharges via /R8, with a time constant of approximately 5·5 minutes. The Machmeter pointer then reverts to normal indications.

23. The output of amplifier 13EB/a feeds the Machmeter indicator AC/AD, via diode 13E/T3/MR9, resistor /R9 and potentiometer /RV501 which is preset for the correct meter sensitivity.

Chapter 2

ALTIMETERS

List of Contents

List of Illustrations

Introduction

1. The aircraft pressure-operated altimeters are represented by electrically-driven instruments; a repeater instrument on the GCA panel is provided for the use of the radio aids instructor.

ALTIMETERS CIRCUIT (/219)

2. The pilots' and instructor's altimeters are driven by two three-phase servo systems, the transmitters of which are actuated by the height servo of the height and touchdown system (Part 8, Chap.7). The height servo shaft drives the rotors of torque transmitters 13ES/TX1 and /TX2 that are energized with 115V, 400c/s. The induced current in the stators is supplied to torque receivers which are housed in the respective instruments.

3. Synchro /TX1 provides drive for the co-pilot's altimeter AB/AD and for the instructor's altimeter 22AF/M2 on the radio aids console; synchro /TX2 drives the pilot's altimeter AC/AG. The rotors of the receiver synchros are energized with 115V, 400c/s, and are coupled directly to the 0 to 1000 feet pointer of the instruments so that one servo revolution equals 1000 feet.

4. The altimeters are provided with the usual barometric pressure setting knobs and a flag which shows a striped sector when the indicated altitude is less than 10 000 feet.

Chapter 3

VERTICAL SPEED INDICATORS

List of Contents

List of Illustrations

Introduction

1. The vertical speed (rate of climb) indicators are fitted on the pilot's and co-pilot's main instrument panels. Normally, these instruments are operated by a differential-pressure system; in the simulator, however, they are d.c. meters, actuated by signals from the flight computer.

VERTICAL SPEED INDICATORS CIRCUIT (/209)

2. The circuit of the vertical speed indicators consists of two moving-coil meters, AC/AH and AB/AG, that are series-connected to the output of amplifier 13EB/b. The amplifier is fed with the vertical component of airspeed V_T. Due to the absence of V_T potentiometers the V_T signal is computed, in the height and touchdown system (Part 8, Chap.7), from functions of height (Z) and Mach number (M). The product of n_1 f(Z) f(M) is applied to amplifier 13EB/b via scaling resistor 13E/T3/R12. Feedback resistor 13E/T3/R11 establishes the amplifier gain; the parallel-connected capacitor /T3/C2 provides a realistic delay on the response of the indicators.

3. The aircraft vertical speed indicators are fitted with non-linear scales that are necessary for the correct indication of the pressure-operated instruments. In the simulator, the linear response of the moving-coil meters necessitates diode shaping circuits, at the output of amplifier 13EB/b, to produce the required deflection of the electrically-driven instrument pointers.

4. The diode shaping circuits consist of two symmetrical diode networks, fed from the +50V and -50V signal lines, respectively, to provide equal shaping of positive and negative output signals. Diodes 13E/T3/MR2 and /MR3 conduct when the amplifier negative output potential exceeds the positive potential present at the wipers of potentiometers 13E/T3/RV17 and /RV15, respectively; a conducting diode switches the respective feedback resistor (/R13, /R14) across the amplifier to reduce the amplifier gain and, thus, the relevant meter pointer deflection is also reduced.

5. Diodes 13E/T3/MR4 and /MR5 operate in a similar manner to /MR2 and /MR3; however, because the diodes are connected in the 'opposite' sense, they are biased by a negative supply and conduct when the amplifier positive output exceeds the negative potential at the wipers of 13E/T/RV20 and /RV22, respectively.

6. The output signal of 13EB/b is fed to the series-connected meters AC/AH and AB/AG via current-limiting resistor 13E/T3/R23 and preset potentiometer 13E/T3/RV502. The setting of /RV502 determines the sensitivity of the meters.

Chapter 4

STAND-BY COMPASS

List of Contents

List of Illustrations

Introduction

1. The aircraft is equipped with a master compass system and a stand-by, type E2B, magnetic-compass. The C6F master compass is incorporated in the flight systems (Part 9, Chap.3); the stand-by compass is mounted, centrally, on the cockpit coaming. The stand-by compass is direct-reading and incorporates a moving magnet that is attached to a fully-floating 360° scale. The E2B compass is used as a stand-by instrument if the master compass system fails; it can also be used for functional checks of the master compass system but is only accurate to within $\pm 5^{\circ}$.

STAND-BY COMPASS CIRCUIT (/338)

2. The circuit of the stand-by compass comprises desynn-transmitter 22AF/A/TX4 and receiver/indicator AD/AB; the receiver/indicator is located in the stand-by compass housing. The transmitter contains a toroidal resistance winding with three equally-spaced tappings, each of which is directly connected to the three receiver stator-coils. Two, separate, diametrically-opposed wipers of the transmitter are connected to +28V and earth, respectively, and are coupled directly to the shaft of the heading servo (heading system, Part 8, Chap.8); one revolution of the shaft equals a heading change of 360°. As the transmitter wipers rotate, the varying potentials

from the resistance winding provide corresponding changes in magnetic field of the receiver coils. The compass scale is attached to a permanent magnet which is suspended in the magnetic field; the magnet thus assumes a position corresponding to the position of the transmitter wipers. The compass scale is illuminated by an integral lamp, the illumination intensity of which is controlled by a dimmer switch in the cockpit (cockpit lighting system, Part 10, Chap.10).

Chapter 5

TURN AND SLIP INDICATORS

List of Contents

List of Illustrations

Introduction

1. The aircraft is fitted with two turn and slip indicators that are mounted on the pilot's and co-pilot's instrument panels. The turn indicator employs a "rate" gyro as a reference for measurements of the angular (turning) movement of the aircraft. The slip indicator is a simple type of lateral accelerometer that indicates the amount of "slip" or "skid" when the aircraft is yawing.

2. In the simulator, the slip and turn pointers of the instruments are actuated by two independent moving-coil mechanisms that are housed in the instrument cases. The electrical driving signals are obtained from the appropriate loops of the flight computer.

TURN INDICATORS (/209)

3. The turn indicator moving-coil meters, AA/AF and AB/AH, are parallel-connected and are fed directly with the yaw rate signal ($\dot{\gamma} - \omega_3$) obtained from the yaw loop of the roll, yaw and sideforce loops system (Part 8, Chap.5). This signal is dependent on the rudder deflection angle, and other yaw-producing component forces, and approximates to the rate of turn for the required range of indications.

4. The circuits of the moving-coil meters include voltage-dropping resistors and potentiometers (i.e., 13E/T3/R33 and /RV508 for the pilot's instrument), and contact sets of relays that represent, when operated, the availability of the required electrical supplies as follows:

(1) Relay 13E/T1/RL1 is energized when the PILOT TURN & SLIP IND circuit breaker PH/128 is made.
(2) Operated relay /RL3 represents the availability of the essential d.c. busbar supplies.
(3) Operated relay /RL4 similarly represents the availability of the main d.c. busbar supplies.
(4) Relay /RL2 is energized when the COPILOT TURN & SLIP IND circuit breaker SG/121 is made.

The No.1 contact sets of these relays complete the earth connections of the two indicators; the No.2 contact sets of relays /RL1 and /RL2 complete the supply circuit to the pilot's and co-pilot's TURN/SLIP POWER indicators, AA/AK and AB/AJ respectively.

<u>SLIP INDICATORS</u> (/209)

5. The slip indicator moving-coil meters are series-connected and are fed, via sensitivity-setting potentiometer 13E/T3/RV507, with the sideforce signal $\frac{F_2}{M_T}$ which is computed in the sideforce loop of the roll, yaw and sideforce loops system (Part 8, Chap.5). The ball-type display on the sideslip indicator is simulated by the ball-shaped pointers of the moving-coil meters, AA/AF and AB/AH.

PART 12

RADIO AIDS

Chapter 1

GENERAL DESCRIPTION

List of Contents

List of Illustrations

Introduction

1. The radio aids computer provides simulation of en-route radio-navigational aids, communication, approach and let-down facilities, aircraft intercom, and GCA talk-down. The track of the simulated aircraft is recorded continuously on two inter-dependent charts, on which an instructor can observe the aircraft progress during a flight training exercise.

2. Eight ground stations are simulated and can be positioned independently on any desired site within the areas of the two charts. The stations can represent non-directional beacons, VOR or ILS installations, or medium frequency ADF beacons, depending on the frequencies allocated to the stations by the instructor.

3. The chart-recorder systems supply radio bearing- and distance-signals to the radio-navigational computing systems; the heading and speed signals, that position the chart recorder pens, are derived from the flight computer. Thus, a closed

control-loop is established as shown in Fig. 1, the loop being completed by the crew. The radio aids console instructor completes a second closed control-loop via the communication channels.

4. A.C. computing amplifiers and a.c. servo systems are employed throughout the radio aids systems to ensure accuracy of synchro-resolution and low drift

5. The main features of the radio aids computer are described in para. 6 to 16, inclusive; a simplified block diagram of the radio aids installation is shown in Fig. 2.

Radio-navigational aids

6. Four radio-navigational receivers are simulated: VHF NAV 1, VHF NAV 2, ADF 1 and ADF 2. The frequencies selected by the pilot are conveyed from the frequency-controllers in the cockpit to a digital tuning system in the radio aids computer. The selected receiver-frequencies are compared with the station frequencies to produce an "in-tune" signal and indication. The eight station frequencies are selected by means of switches on the radio aids console.

7. When a VHF or ADF receiver/station "in-tune" state is achieved, the co-ordinates of the station are automatically routed from the chart system to the relevant bearing computation system. The computed aircraft-to-station bearing and distance is fed to the cockpit instruments and to the repeat-display instruments on the radio aids console.

8. Full VOR and ILS facilities, including automatic reception of ILS markers, are simulated. The audio idents are obtained from a sixteen-channel continuous-loop tape recorder mounted on the audio drawer of the radio aids console. The tape recorder provides idents for ILS markers and five fan markers which can be selected manually by the instructor. The remaining eight tracks of the tape recorder are allocated to the eight station sites.

9. GCA glidepath deviation, aircraft-to-runway distance, and course deviation are displayed continuously on indicators on the GCA panel of the radio aids console. The GCA panel also contains the bearing scale and pointer of a GCA bearing actuator. The use of a station as a GCA facility is at the instructors discretion.

Communication systems

10. Air-to-ground communication is achieved, by selection of the COMM channels, via the audio system. The crew can communicate with the radio aids console instructor (who is provided with a repeat-indication of the crew's COMM frequency

controller setting) and/or with the flight instructor.

11. Normal intercom facilities are provided between crew members; the crew can also communicate with the flight instructor and with the console instructor.

12. When ADF or VHF NAV facilities are in use, the appropriate station idents and/or marker idents are mixed with variable degrees of shot noise (to simulate static noise, etc.) and are fed to the crew's headsets via the audio system.

Chart recorders

13. Two chart recorders are mounted vertically on the radio aids console. A large-area chart represents an area of 320 x 320 nautical miles, and a small-area chart represents an area of 80 x 80 nautical miles. The recorder pens trace the track of the simulated aircraft, in response to heading, airspeed, wind-speed and wind-direction signals. Tracking from large-area to small-area charts (and vice-versa) is continuous. If the simulated aircraft moves out of the area of the small-area chart, the small-area chart pen tracks around the periphery of the small-area chart while the large-area chart pen continues the aircraft track. If the aircraft re-enters the range of the small-area chart, the small-area chart pen immediately continues the track from the correct position at the edge of the chart.

14. The area represented by the small-area chart can be positioned anywhere within the coverage of the large-area chart; the pens can also be positioned manually by the instructor.

Instructor's controls

15. The radio aids console contains a number of controls that enable an instructor to preset various flight parameters. These controls are located as follows:

(1) VHF NAV panels contain an ILS glide slope selector switch, middle marker and outer marker distance controls, and a localizer course line setting control.

(2) The GCA panel contains a magnetic variation control, the setting of which modifies the heading signal fed to the chart recorder systems, a GCA course line control, and a GCA station selector switch.

(3) An "atmosphere" panel contains controls for the adjustment of airfield height, barometric pressure, wind speed, and wind direction.

(4) The station panels contain station frequency selection switches, and potentiometers for setting the co-ordinates of the stations. A small panel

fitted with nulling-meters for accurate positioning of the station sites on the small-area and large-area charts is located above the station panels.

(5) The audio drawer houses the tape recorder; the front panel of the drawer contains controls for setting the levels of crash and static noise fed into the audio systems, for adjusting audio marker volume, marker selector switches, a microphone selector switch, and volume controls for the microphone and headphones. Also fitted in the audio drawer is a morse key for use during the recording of coded idents, and the associated tape recorder controls.

16. In addition to the controls described in para.15, the radio aids console panels contain fail switches, on/off switches, and indicator lamps. A complete description of these controls and switches is given in Part 2, Chap.2.

State panel

17. The state panel, 21BB, enables the servicing personnel to check the operation of the station and receiver ring counters of the station selection digital system (Chap.3). Eight station, two ADF, one IN TUNE and two NAV indicators display the station and receiver address which can be changed sequentially, during tests, by operation of a ONE SHOT button in conjunction with a NORMAL/ONE SHOT switch. A WARNING TEST lamp is included on the state panel and lights when the one-shot facility is in use.

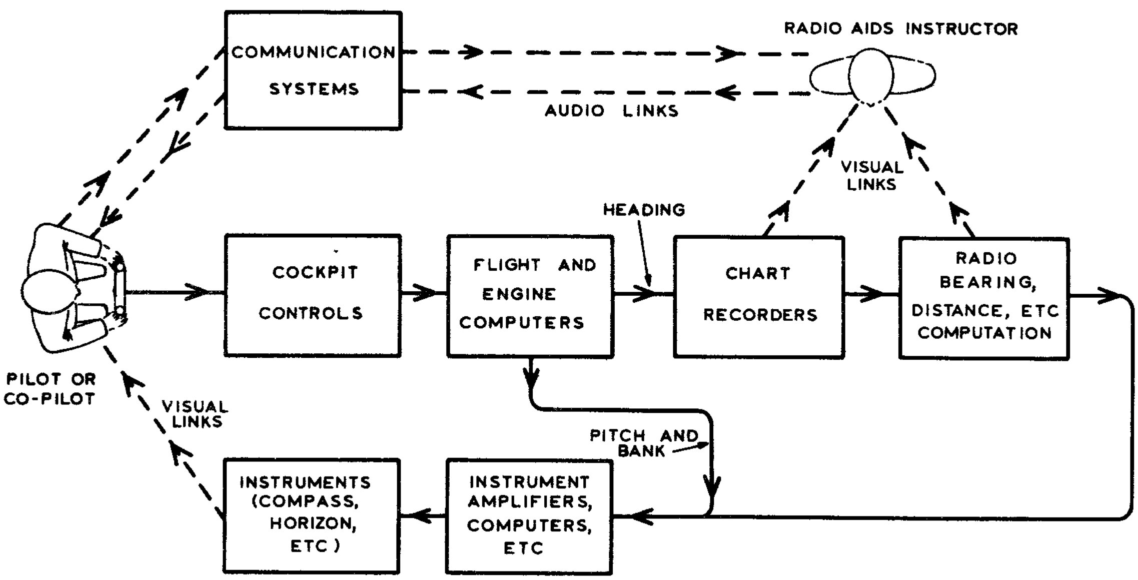


Fig 1 Control loops

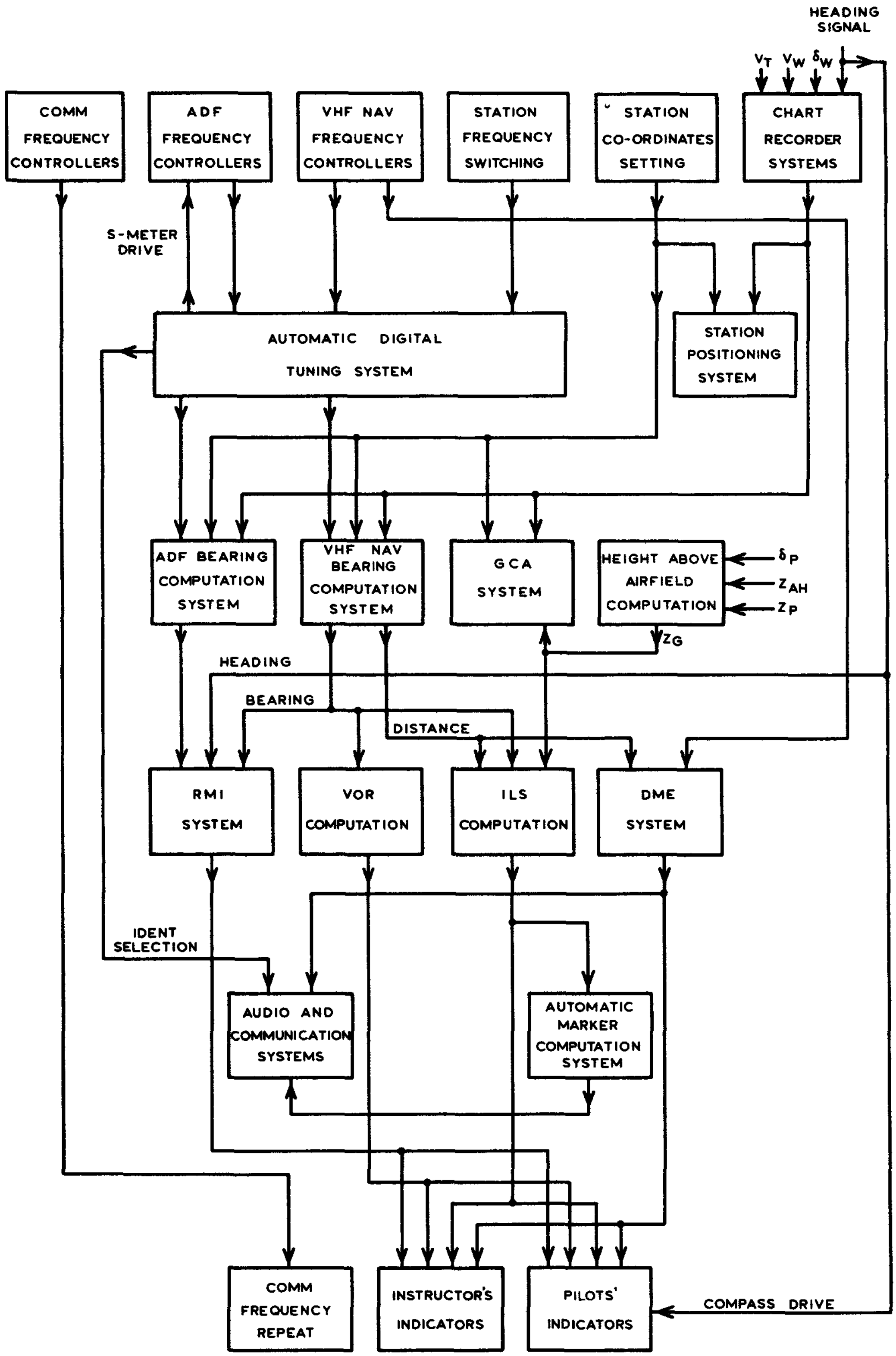


Fig. 2 Radio aids — block diagram

Chapter 2

CHART RECORDER SYSTEM

List of Contents

List of Tables

List of Illustrations

Introduction

1. The chart-recorder system provides a graphical presentation of the computed position and track of the simulated aircraft. Two interdependent charts are used: a large-area chart, representing an area of 320 x 320 nautical miles to a scale of $1:10^6$, and a small-area chart representing an area of 80 x 80 nautical miles, scaled at 1:250 000. Each chart has an actual usable area of 24 x 24 inches. The aircraft track is traced, on transparent plastic panels that overlay the charts, by Rapidograph pens fitted to a conventional X-Y plotting mechanism.

2. The recorder mechanisms are actuated by servo-motors that are controlled by electrical signals representing the Cartesian co-ordinates of the simulated aircraft position. These co-ordinates are computed from the resolved polar co-ordinates of the aircraft heading (δ), true airspeed (V_T), wind direction (δ_W) and wind speed (V_W) Thus, the movement of the pens is proportional to track and groundspeed. V_T is derived from the flight computer, and δ is derived from the heading servo (Part 8, Chap.8). V_W and δ_W signals are obtained from the wind speed potentiometer and wind direction resolver (instructor's controls), respectively. These controls are located on the "atmosphere" panel (22AG) of the radio aids console, and can be adjusted to provide values of V_W from 0 to 150 knots, and of δ_W through 360^o.

3. The local deviation between magnetic and true North is set by means of the MAG VAR control on the GCA panel (22AF). The MAG VAR control operates, between limits of 30^o west and 30^o east, to offset the stator of the resolver that supplies the initial heading signal to the chart-recorder servos. The heading servo drives the compass cards and is unaffected by the MAG VAR control. Thus, the setting of the MAG VAR control results in an angular deviation between the track traced by the pens and the compass magnetic heading displayed on the cockpit instruments (neglecting wind effects).

4. Radio bearings and distances are computed from signals supplied from the chart-recorder positional potentiometers. The effect of MAG VAR on these signals is introduced by means of further MAG VAR resolvers.

5. The radio aids console instructor uses the station positioning system (para. 41) to set the eight simulated radio aids stations to any required position on the charts, and to set the small-area chart datum, (which is the bottom left-hand corner of the small-area chart), to any position within the large-area chart. Accurate station positioning is achieved by manual setting of the recorder pens to the required station location, followed by adjustment of the station co-ordinates-setting potentiometers on the station panel (e.g., 21AC) to obtain a zero-reading on northings and eastings null indicators (on the co-ordinate positioning panel, 21AA).

6. The reference supply for the servo-motor field windings can be disconnected by ON/OFF switches mounted to the right of each chart. Operation of these switches to the OFF position thus permits an operator to position the pens on the appropriate charts by means of the manual control knobs located adjacent to each chart.

7. When the aircraft is computed to be within the area of the small chart, the small-chart circuit is master, and integrates the aircraft- and wind-velocities to give the co-ordinates of the aircraft position. Under these conditions, the large-chart pen servo is slaved from the small-chart circuit. When the aircraft position is computed to be outside the small-chart area, the large chart is master and slaves the small-chart pen, which then tracks along the appropriate section of the periphery of the small chart. The mode of operation is determined by relays that are energized by limit switches fitted to the small-chart mechanism.

8. The chart-recorder systems employ a.c. servos and amplifiers throughout. The a.c. signals and reference supplies are obtained from the radio aids 400c/s supplies.

<u>CHART RECORDERS</u> (/321, /320 and /323)

9. Each chart system circuit includes a northings and an eastings servo for positioning the pen along the north-south and east-west axes, respectively. When the small-chart pen is within the limits of the small-chart area, and the computer airspeed $V_T \neq 0$, the two chart-recorder circuits are interconnected as shown in Fig.1, with all "small chart on limits" relays de-energized.

10. The small-chart co-ordinates are computed according to the equations:

$$Ya = \int_0^t (V_T \cos\delta + V_W \cos\delta_W)\, dt + \text{northings component of MAG VAR}$$

$$Xa = \int_0^t (V_T \sin\delta + V_W \sin\delta_W)\, dt + \text{eastings component of MAG VAR}$$

where Ya = aircraft northings
and Xa = aircraft eastings.

The terms of the two integrands are obtained from the heading resolver and wind resolver (/321) as follows:

(1) $V_T \cos\delta$ and $V_T \sin\delta$ are obtained from the stator windings of the heading resolver 22AF/A/RS1. The rotor winding (R1, R2) of /RS1 is fed with the V_T signal from amplifier 26AJ/b, which buffers the product of M and Z from M potentiometer 13CS/RV2 and Z potentiometer 13ES/RV1. V_T is produced at the output of amplifier 26AJ/b as an a.c. signal represented by the equation:

$V_T = 1121\ M\ f(Z)$

where $f(Z) = 1$ - when $Z = -1000$ ft
$f(Z) = 0{\cdot}864$ - when $Z = +37\ 250$ ft.

Aircraft heading δ is introduced into this term by the positioning of the rotor of /RS1 by the heading servo. The MAG VAR control, situated adjacent to the heading resolver dial on panel 22AF, is coupled to the stator of the heading resolver; a preset angular displacement of up to $\pm 30^\circ$ can thus be introduced between the rotor and the stator of 22AF/A/RS1.

(2) $V_W \cos \delta_W \sin \delta_W$ are obtained from the stator windings of the wind direction resolver 22AG/RS1. The rotor winding (R1, R2) of this resolver is fed with a signal representing wind speed V_W from the wiper of WIND SPEED potentiometer 22AG/RV3, δ_W being set by means of WIND DIRECTION control coupled to the rotor of resolver 22AG/RS1.

These terms are summed at the inputs of their respective servo amplifiers, and are integrated electro-mechanically to produce the appropriate Cartesian co-ordinates for the small-chart pen. The small-chart eastings and northings servos are identical except for component references; only the small-chart northings servo is described.

11. The signals representing polar co-ordinates $V_W \cos \delta_W$ and $V_T \cos \delta$ are fed, via released contact sets 26A/RL1/3 and /4 and summing resistors /R4 and /R5, to the input of buffer amplifier 26A/Ga. The output of 26A/Ga is connected to the input of servo amplifier 26A/A, the output of which drives the small-chart northings servo motor 24AA/X2. The tacho-generator section of /X2 provides a velocity-feedback signal which is connected to the input of amplifier 26A/Ga, via released contact set /RL2/1 and scaling resistor /R1.

12. The small-chart aircraft northings signal (Ya) is taken from the wiper of positional potentiometer 24AA/RV2 and is connected to the summing input of buffer amplifier 26A/Ha (large-chart servo, /320), via released contact set /RL3/3 and resistor /R124.

13. The small-chart datum signal -Ys, obtained from the wiper of the SET SMALL AREA DATUM potentiometer 21AA/RV2, is inverted by amplifier 21C/Ja to produce Ys, and is connected to the input of the large-chart northings servo, via released contact set /RL1/1 and /R126. Velocity-feedback is not applied to the large-chart servo (contact set /RL3/4 released) when the small chart-recorder is master. The large-chart pen is, therefore, positioned along the northings axis by Ya +Ys. Positional feedback of the large-chart northings servo loop is supplied from the output of buffer amplifier 26A/Ka, via released contact set /RL4/3 and resistor /R125, to the input of 26A/Ha.

14. The small- and large-chart eastings servos operate in a similar manner to the northings servos, the small-chart pen being positioned by electronic integration, and the large-chart pen being positioned by a signal representing the sum of the aircraft eastings and the small-chart datum, Xa+Xs. Figure 1 shows the basic interconnections between the components of the chart-recorder system when the small-chart system is the master integrator. Figure 2 shows the circuit configuration when the computed position of the aircraft is outside the area of the small chart, and the large-chart system is the master integrator.

15. Limit microswitches are fitted to the north, south, east and west limits of the small-chart mechanism. If any one of these limits is reached by the small-chart pen, the respective motor is stopped and the large chart becomes master, slaving the small chart. For example, if the north limit is reached, the "north" microswitch makes and energizes relay 26A/RL5 (/321). Operated contact set /RL5/1 connects the d.c. output of the type ZMA p.s.r. unit 26A/Da to the coil of /RL28 via diode /MR32. The output of the p.s.r., which is fed from an output of the servo-drive amplifier 26A/A, is positive when the motor is "running north", and /RL28 is therefore energized. Contact set /RL28/1 releases and disconnects the 115V, 400c/s, reference phase supply for the field winding of servo-motor 24AA/X2, which then stops. When the motor is subsequently required to move the pen away from the limit, the output of the p.s.r. changes polarity, /RL28 de-energizes, and the motor field winding is reconnected. Similar discriminators operate for the south, east and west limits.

16. When $V_T = 0$, contact set 13B/T1/RL4/4 is released and relays 21A/RL9 and 26A/RL36 (/320) are energized. Contact sets of /RL9 operate and open-circuit the field windings of all four chart servo motors, thus preventing pen-drift. Contact sets of /RL36 operate in the heading servo system (Part 8, Chap.8) and in the glide-path computation circuit (ILS/VOR systems, Chap.6) to prevent drift at $V_T = 0$. Relay 13B/T1/RL4 operates in the drag loop (Part 8, Chap.2).

17. A small, in-phase, a.c. bias is fed to the input of both of the small-chart servo amplifiers whenever one of the limits is reached. This bias voltage, which is connected via an operated contact set of the respective limit relay, prevents the small-chart pen "hunting" against the limit. Preset potentiometers permit adjustment of the bias voltage during initial setting-up tests. For example, when the small-chart pen reaches its north limit, /RL5 (/321) is energized and contact set /RL5/3 connects the 40V, 400c/s, supply to the summing input of amplifier 26A/Ga, via /R57, preset potentiometer /RV57 and /R56.

18. When any one of the small-chart limit switches is operated, a contact set of the energized limit relay (26A/RL5, 6, 7 or 8) operates and energizes relays 26A/RL1, 2, 3, 4 and 10 (/323). Contact sets of the latter group of relays switch the

interconnections between the two chart-recorder circuits so that the large-chart pen is positioned by the integrated aircraft- and wind-velocity signals and the small-chart pen is slaved from the large-chart positioned-potentiometer signals. This is the condition illustrated in Fig.2.

19. The servo-motor field windings can be disconnected by operation of switches 23AA/S1 (small chart) and 25AA/S1 (large chart) to facilitate manual pen-positioning.

20. When the aircraft position is outside the area of the small chart, the pen tracks along the appropriate section of the small-chart periphery; thus, when the aircraft re-enters the small-chart area, the pen is positioned correctly to commence tracing the aircraft track. The positional signals fed to the small-chart system, while the pen is tracking along the periphery, are:

(1) Ya - Ys to the northings servo
(2) Xa - Ys to the eastings servo.

The signals (-Ys and -Xs) from the wipers of the SET SMALL AREA DATUM potentiometers (/320) are fed direct to the small-chart servos via operated limit-relay contact sets /RL10/3 and /RL10/4 (/321).

21. The northings and eastings signals, from both large- and small-chart positional potentiometers, are fed to the radio aids computer, where they are processed to provide aircraft-to-station bearing and distance signals. For example, the small-chart northings signal, from the wiper of 24AA/RV2 (/321), is inverted by amplifier 26A/Ca, and is fed to the MAG VAR resolver 22AF/A/RS2. This resolver modifies the signals by the amount of magnetic variation applied. The resultant signals are then fed to amplifiers 26A/Ea and 26A/Eb which in turn feed into the radio aids computer.

RECEIVER TUNING DISCRIMINATION (/323)

22. The radio aids console instructor or operator can allocate any of eight simulated radio aids ground stations to sites within both the large- and small-chart areas. A chart selector switch, which can be set to LARGE or to LARGE/SMALL, is provided on each station co-ordinate setting panel adjacent to the co-ordinate setting potentiometers (para.31). When a chart selector switch is set to LARGE, the co-ordinates of the particular station and of the simulated aircraft (used in bearing computations) are obtained from the large-chart station sitings (para.31) and from the large-chart positional potentiometers, irrespective of the relative positions of simulated aircraft and charts. When a chart selector switch is set to LARGE/SMALL, the station and aircraft co-ordinates are those related to the small chart if the aircraft position is within the small-chart limits, or to the large chart if the aircraft position is outside the small-chart limits.

23. When a chart selector switch is set to LARGE, a relay is energized and its contact sets select the large-chart co-ordinates potentiometers in the station co-ordinates setting system. For example, when switch 21AC/S1 is set to LARGE, +28V is connected to the coil of 21AC/RL1; contact sets of /RL1 select station 1 large-chart co-ordinates.

24. When set to LARGE, 21AC/S1 also connects +28V to released contact sets 22BC/RL1A/3, /RL1J/3, /RL2A/3 and /RL2J/3. When operated, these contact sets represent, respectively, radio aids receivers 1, 2, 3 and 4 "in tune" with station 1. Similarly, contact sets of "receiver-to-station" tuning relays operate when any receiver is "in tune" with any one of the remaining seven stations (station selection digital system, Chap.3). If receiver 1 is "in tune" with station 1 and switch 21AC/S1 is set to LARGE, then "receiver 1 tuned to large station" relay 21B/RL2 is energized. Contact sets of /RL2 operate in the ADF 1 bearing computation circuit (/324), where they provide selection of large-chart aircraft eastings and northings co-ordinates. Relays 21A/RL2, 21B/RL7 and 21B/RL23 operate similarly when receivers 2, 3 and 4, respectively, are "in tune" with station 1.

25. The various combinations of station and receiver "in tune" conditions are achieved by the interconnection of the "in tune" relay contact sets; the appropriate "receiver tuned to large station" relay is energized if the corresponding station panel chart selector switch is set to LARGE.

26. When a chart selector switch is set to LARGE/SMALL, the co-ordinates allocated for the corresponding station are obtained from either the small-chart circuit or the large-chart circuit, depending on whether the computed aircraft position is within or outside the small-chart area. If any chart selector switch (e.g., 21AC/S1), on a station panel, is set to LARGE/SMALL, subsequent operation of "receiver tuned to large station" relays 21B/RL2, 21A/RL2, 21B/RL7, or 21B/RL23 (when "in tune" with the corresponding station) will depend on the operation of the small-chart limit relays. With the aircraft position inside the small-chart limits, the limit relay contact sets (e.g., 26A/RL5/2) are released; the station co-ordinate relay (e.g., 21AC/RL1) is de-energized and its contact sets select the small-chart station co-ordinates (para.33). Similarly, the "receiver in tune with large station" relay remains de-energized and the appropriate radio-navigational aid obtains its co-ordinates from the small-chart system circuit.

27. If the small-chart pen reaches one of its limits, the contact set of the associated limit relay (e.g., /RL5/2) operates and connects +28V, via the LARGE/SMALL pole of the corresponding chart selector switch, to the coils of the station co-ordinate relay and the "receiver tuned to large station" relay. Co-ordinates are then obtained from the large-chart system circuit.

28. The contact sets of the four "receiver in tune with large station" relays operate in a number of radio aids; Table 1 is therefore included as an aid to cross-reference.

TABLE 1

Relay references

Relay:	Receiver:	Contact sets:	Chapter:	Drg. No.:
21B/RL2	1 (ADF 1)	ADF 1 bearing computation	7	/324
21A/RL2	2 (ADF 2)	ADF 2 bearing computation	7	/325
21B/RL7	3 (VHF NAV 1)	VHF NAV 1 bearing computation	6	/326
		VOR 1 LOC glidepath computation	6	/327
		VHF NAV 1 DME	10	/335
21B/RL23	4 (VHF NAV 2)	VHF NAV 2 bearing computation	6	/329
		VOR 2 LOC glidepath computation	6	/330
		VHF NAV 2 DME	10	/336

29. Relay coil 21B/RL32 is energized when receiver 3 (VHF NAV 1) and receiver 4 (VHF NAV 2) are both "in tune" with the same station. For example, when receiver 3 and receiver 4 are both "in tune" with station 1, contact sets 22BC/RL2A/4 and 22BC/RL2J/4 are operated (station selection digital system, Chap.3) and 21B/RL32 is energized. Operated contact sets of /RL32 permit the ILS/VOR 1 and ILS/VOR 2 indicators to be driven from the ILS/VOR 1 system when both are using the same station (ILS/VOR systems, Chap.6).

30. The No.2 contact set of the appropriate small-chart limit relay (26A/RL5, 6, 7 or 8), when operated, connects +28V to the parallel-connected coils of relays 26A/RL1, 2, 3, 4 and 10, the contact sets of which switch the chart systems from the "small-chart master" to the "large-chart master" mode of operation (para.18).

STATION CO-ORDINATES SETTING AND SWITCHING (/322)

31. The eight simulated ground stations can be positioned to any site on the large and small charts. The station sites are set by large-area and small-area co-ordinate-setting potentiometers located on the four stations panels 21AC, AD, AE and AF. Each station panel contains the potentiometers for two stations. Each potentiometer is helically-wound, with a ten-turn double-pointer dial which is integral with the setting knob. The signal-outputs of the potentiometers represent the distances of the stations north and east of the reference point on the appropriate chart; this reference point is at the bottom left-hand corner of each chart.

32. Selection of large-area or small-area co-ordinate-setting potentiometers depends on the operation of contact sets of relays, the coils of which are energized via the poles of chart selector switches mounted between the station co-ordinates setting potentiometer. These switches are shown on drawing /323 and their operation is described in para. 22.

33. A.C. signals, proportional to the required co-ordinates, are obtained from the wipers of the selected setting potentiometers, are buffered, and fed to the radio aids computer via "receiver/station in-tune" relay contact sets. The coils of these relays operate in the station selection digital system (Chap.3) and are shown on drawing /311. For example, the a.c. signal representing the northings co-ordinate of station 1 on the small chart is obtained from the wiper of potentiometer 21AC/RV3 and is fed, via released contact set 21AC/RL1/1, to the input of buffer amplifier 21C/Aa. The 40V, 400c/s, a.c. supply is connected to the potentiometer via released contact set 21AC/RL1/3. (The small-chart pen is assumed to be within limits, and the chart selector switch set to LARGE/SMALL).

34. The output of amplifier 21C/Aa is fed to contact sets 22BC/RL1A/1, /RL1J/1, /RL2A/1 and /RL2J/1. When the respective receiver is "in tune" with station 1, one of these contact sets operates and connects the output of 21C/Aa to the appropriate radio aid as "station 1 small-area northings".

35. If the small-chart pen is at any of the limits (or if chart selector switch 21AC/S1 is set to LARGE), 21AC/RL1 (/323) is operated and contact sets /RL1/3 (/322) and /RL1/1 connect the large-area station 1 northings potentiometer 21AC/RV7 to the a.c. supply and to the buffer amplifier, respectively.

36. Co-ordinate settings for the remaining stations are achieved in the same manner as that for station 1 northings, described in para. 33 to 35, inclusive.

37. A preset potentiometer is connected in series with the earth return of each co-ordinate-setting potentiometer. Adjustment of the preset potentiometers permits exact coincidence of small- and large-chart station sites to be obtained.

38. A small a.c. bias signal is fed to the input of each buffer amplifier, in anti-phase to the input signal from the co-ordinate-setting potentiometers. This bias signal enables the station site to be set on all parts of the chart area with any magnetic variation selected.

39. The contact sets of the receiver/station tuning relays are interconnected in such a way that if any receiver becomes tuned to more than one station (because of a fault condition) only the lowest-numbered station is selected.

40. For details of the tuning relay coils and contact sets, reference should be made to drawing /312 (relay table).

STATION POSITIONING (/334)

41. The station positioning system enables the radio aids instructor or operator to position:

(1) The small-chart area relative to the large-chart area
(2) The eight simulated stations within the large-chart area
(3) The eight simulated stations within the small-chart area.

42. These settings are achieved using controls on the co-ordinate positioning panel 21AA of the radio aids console. The controls on this panel comprise:

(1) Set SMALL AREA DATUM N and E potentiometers; these are helical potentiometers of the type referred to in para.31
(2) A 10-position NULL SELECTOR switch
(3) Northings and easting null-indicating meters
(4) A (red) warning lamp which lights when the NULL SELECTOR switch is not set to OFF.

43. The NULL SELECTOR switch 21AA/S2 connects the station (or small-chart) northings and eastings signals from the outputs of the station co-ordinate setting system buffer amplifiers (/322) and sums them with the appropriate large- or small-chart aircraft co-ordinates from the chart systems. The sum is applied to the input of amplifier 21A/Cb (northings) and 21A/Ca (eastings), the rectified outputs of which drive the two null indicators, 21AA/M2 and 21AA/M1, via operated contact sets /RL6/2 and /RL6/1. The aircraft co-ordinates are fed from the chart positional potentiometers via inverting buffer amplifiers (para.21); the output of each summing amplifier (and the null indicator readings) will, therefore, be zero when the station co-ordinates signals are of the same amplitude as their respective aircraft co-ordinates from the chart system.

44. The chart pens can be positioned manually to any required station site; accurate station co-ordinate settings can thus be obtained by adjustment of the station co-ordinate potentiometers for zero-readings on the null indicators. Similarly, the small-chart datum can be positioned relative to the large chart by adjustment of the SET SMALL AREA DATUM potentiometers. For this purpose, the voltages at the wipers of the SET SMALL AREA DATUM potentiometers are connected, via amplifiers 26A/Ha and 26A/Hb (/320), to the station positioning system. Zero readings are obtained when the settings of the datum potentiometers coincide with the co-ordinates from the large-chart system.

45. Large- or small-chart co-ordinates are selected by SMALL/LARGE switch, 21AA/S1. The NULL SELECTOR switch has ten positions, OFF, 1 to 8 inclusive (to correspond to each one of the eight simulated stations) and SMALL AREA. Four wafers of the NULL SELECTOR switch select the appropriate station or small-chart co-ordinates; a fifth wafer is used to connect +28V to the coil of 21A/RL6 and to the warning lamp 21AA/LP1 when the switch is in any position other than OFF. When the NULL SELECTOR switch is at OFF, /RL6 is released and its contact sets disconnect the null indicators from the amplifier outputs.

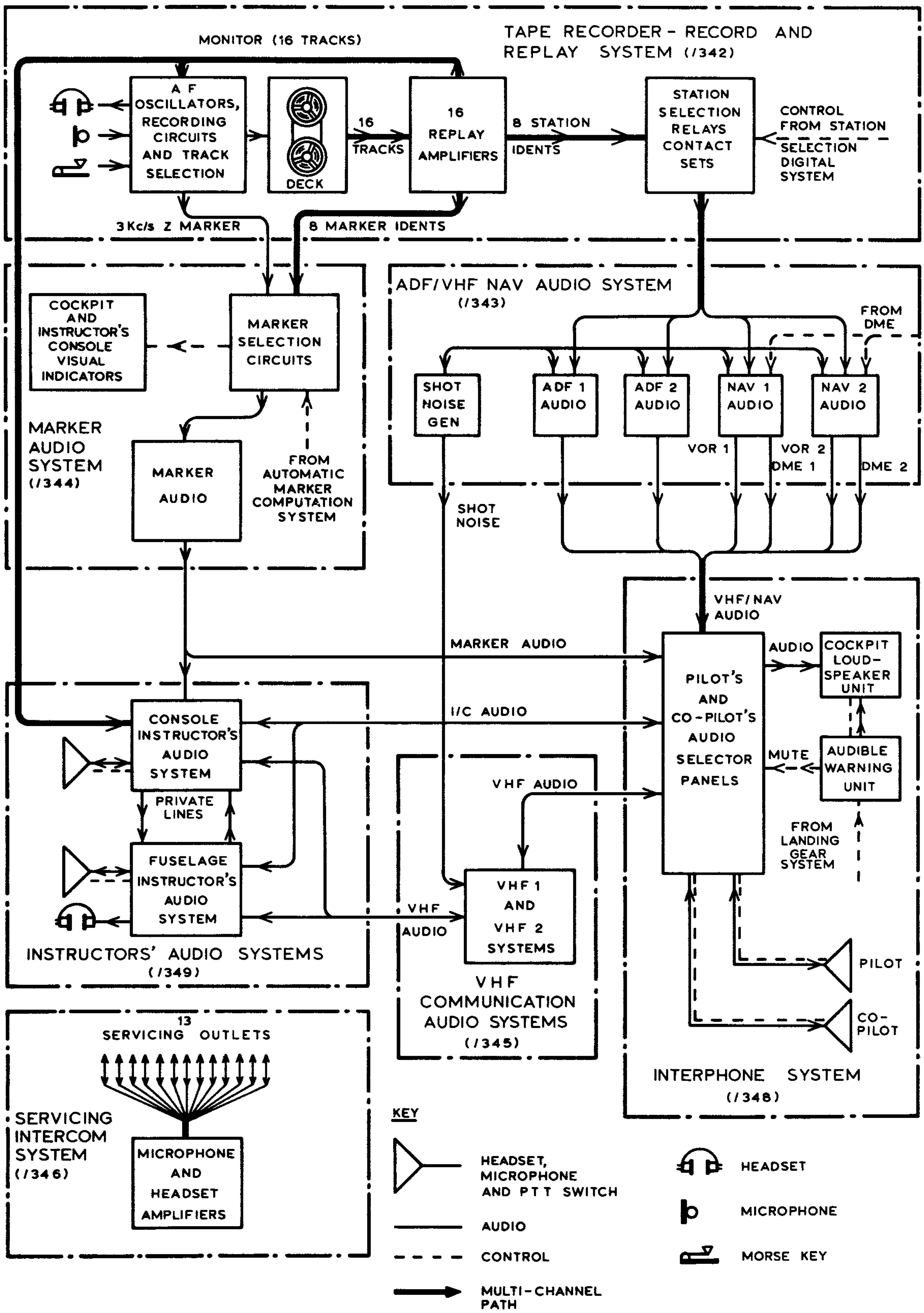


Fig 1 Audio systems — block diagram

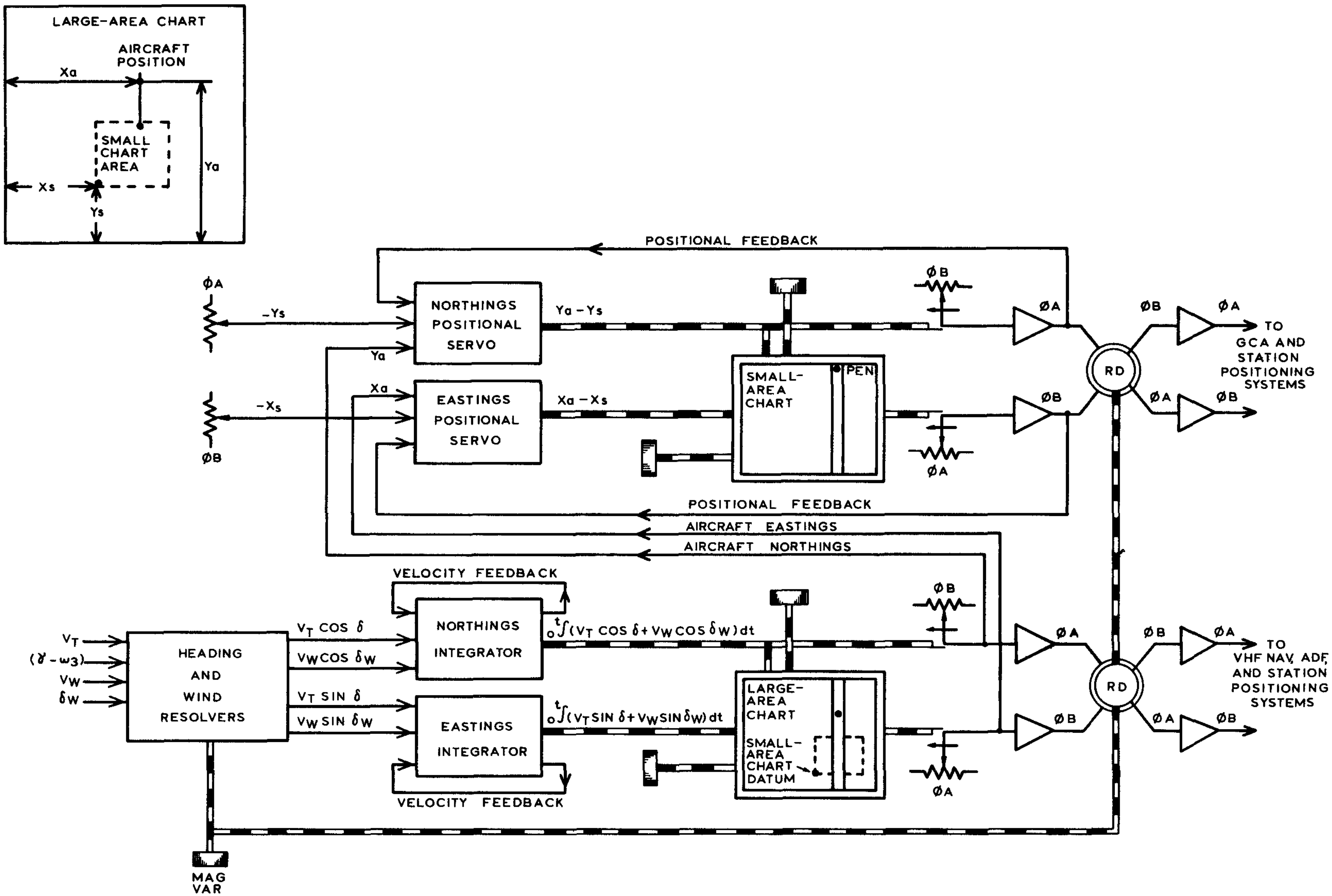


Fig 2 Aircraft position outside small-chart area

Chapter 3

STATION SELECTION DIGITAL SYSTEM

List of Contents

List of Illustrations

List of Illustrations (Cont'd.)

Introduction

1. The radio aids station selection digital system enables the radio aids instructor, during a flight training exercise, to allocate a numerical value representing a "selected frequency" to any one of eight simulated radio stations. Four simulated radio aids receivers, ADF1, ADF2, NAV1 and NAV2, are frequency-controlled from the associated receiver control-panels in the cockpit. The station selection system employs a digital automatic "tuning" system which determines whether or not a particular receiver is "in tune" with a particular station. Visual indications are made on the appropriate receiver and station panels of the instructor's radio-aids console, when any one of the four simulated receivers is "in tune" with any one of the eight simulated stations. The "in tune" information is passed also to the receiver tuning discrimination system (Chap.2), to the audio and intercommunications system (Chap.5) and to the radio aids bearing computation systems (Chap.6 and 7). An explanation of the logical symbols used in the associated logical drawings of the system, is given by the symbol drawing /300 (Part 6, Chap.2). The selection system utilizes conventional digital techniques embodying transistorized logical circuit-elements, the circuit descriptions of which are given in Part 5, Chap.6.

LOGIC THEORY

2. The station selection digital system uses binary numbers in all the required logical operations. A binary number is inherently less complex, although of greater length, than its decimal equivalent and its two digit-values, 0 or 1, may be conveniently represented by the two stable states of a simple, basic, electrical or electronic circuit, e.g., a relay or a bi-stable flip-flop. The circuits used in the station selection digital system are mounted on digital boards which are individually described in Part 5, Chap.6A to 6H.

Binary notation

3. A binary digit ("bit") is used to form "words", a word being a number of bits arranged in the order of their numerical significance. A typical binary number has the form:

$$\begin{aligned} 10101 &= (2^4 \times 1) + (2^3 \times 0) + (2^2 \times 1) + (2^1 \times 0) + (2^0 \times 1) \\ &= 16 + 0 + 4 + 0 + 1 \\ &= 21. \end{aligned}$$

It is important to note that the decimal value (significance) of the binary bit increases by a single power of the radix 2 each time its position is changed by one place (from right to left). This convention, of course, follows the normal decimal positional notation pattern, where the value of the digit increases by a single power of the radix 10 when the digit is moved one "column" to the left.

Binary coded decimal

4. The binary coded decimal (BCD) system is used throughout the station selection digital system to simplify binary-to-decimal conversion. When using BCD, a decimal number is broken down into its component digits (units, tens, hundreds, etc.) and each decimal digit is represented by its binary equivalent. Four bits are, therefore, needed to represent one decimal digit (0 to 9 inclusive). For example, a BCD number, representing the decimal equivalent of 953, say, has the form:

Hundreds	Tens	Units
1001 (binary equivalent of 9)	0101 (binary equivalent of 5)	0011 (binary equivalent of 3).

Binary subtraction by comparison

5. The normal arithmetic functions of addition and subtraction employing the conventional "carry" and "borrow" methods may be performed upon binary numbers although no arithmetic functions of this kind are performed in the station selection system. A form of simple subtraction by comparison of binary bit-values is, however, used in the system.

6. In this method, two BCD numbers are arranged to provide two separate 19-bit words which are each fed, in parallel, to a digital comparator circuit. If the corresponding bit in each of the two words is exactly the same value (i.e., both '0' or both '1'), an output representing zero ('0') is obtained from the comparator.

For example:

1st word	1010101	....	(18 bits)
2nd word	1010101	....	(18 bits)
	0000000		

The output of the comparator is a bit-value of '0' only if all the corrèsponding input-bits in each word are the same; if any of the bits are different, no real numerical value is obtained as an answer to the subtraction, but the comparator gives an output (a bit-value of '1') which indicates that the answer is not zero.

Logical relationships

7. Binary logic is based on a form of algebra, known as Boolean, which deals in logical relationships. Use of the Boolean algebraic terms which define these logical relationships, has been adapted to enable a required sequence of electrical or electronic switching-procedures to be expressed in terms of an equation. The terms used to define the two bit-values (logical '1' or logical '0') are translated into two definite values of voltage by the particular electrical or electronic circuit-elements of the digital system. Normally, in transistorized circuits using PNP transistors, a logical '1' is represented by a negative voltage and a logical '0' by 0V; a conversion to positive logic implies that a logical '1' is represented by a positive voltage.

AND-gate

8. The AND-gate produces an output (logical '1') only if all inputs to it are '1' or, by logical conclusion, it may be regarded as producing an output of '0' if any one of the inputs is '0'. Assuming two inputs, A and B, the Boolean equation for the output is A.B (read "A and B"). AND-gates, as such, are not used, in the station selection digital system.

NAND-gate

9. The NAND- ("not" AND) gate is an AND-gate (para.8) followed by an inverter. The "not" output ('0') is produced only if all inputs to the gate are '1', or, by logical conclusion, the gate may be regarded as producing an output of '1' if any one of the inputs is '0'. Assuming two inputs A and B, the equation for the output is $\overline{A.B}$ (read "not A and B").

OR-gate

10. The OR-gate produces an output (logical '1') if any one of its inputs is '1' or, by logical conclusion, it may be regarded as producing an output of '0' only if all the inputs are '0'. Assuming two inputs, A and B, the Boolean equation for the output is A+B (read "A or B"). Two inputs of '0' ($\overline{A}$ and $\overline{B}$) produces $\overline{A}.\overline{B}$ (read "not A and not B").

AUTOMATIC TUNING SYSTEM

11. A block schematic diagram of the automatic tuning system is shown in drawing /301. The outputs of the individual STATION FREQUENCY selection switches which are located on the station panels (21AC, AD, AE and AF) on the radio aids console, provide the frequency information (in BCD) for each of the eight simulated stations. Each station frequency is selected by the instructor, as required, by operation of the six-decade (thousands, hundreds, tens, units, tenths and hundredths) binary-coded-decimal STATION FREQUENCY selection switches. The range of frequency is selected by the KC/S - MC/S switches. This BCD information is encoded on to twenty station frequency busbars (one busbar unused) which are common to all eight stations. The frequency to which each of the four radio aids receivers, ADF1 (Rx1), ADF2 (Rx2), NAV1 (Rx3) and NAV2 (Rx4), is tuned, is encoded (BCD) on to nineteen receiver frequency busbars which are common to all four receivers.

12. A station and receiver ring counter system ensures that the frequency information from each of the receivers is transferred, in a pre-determined sequence, to the busbars, and a frequency comparator compares the bit-values of the selected station frequency value with that of each of the receiver frequencies.

13. Assume that station 4 (shown on drawing /301) is set to a frequency of 111·0Mc/s (as determined by the STATION FREQUENCY selection switches) and that receiver 3 (NAV1) is also set to 111·0Mc/s (as determined by the NAV1 receiver frequency selection controls in the cockpit). A single logical '1 circulates through the station ring counter (stations 1 to 8, /301) at the command of the clock @1 pulse; the frequency information from each station is, therefore, transferred, in turn, to the station frequency busbars. For each complete circulation of the logical '1' through the station counter, the logical '1' circulating in the receiver ring counter (receivers 1 to 4, /301) progresses one stage (due to the output from station 8). When the receiver 3 and the station 4 counter-positions are in coincidence, the digital information on the receiver and station frequency busbars is compared by the frequency comparator and, because the frequency information on the busbars is the same (111·0Mc/s), the comparator produces an output to the "in tune" busbar; this output is fed to all four receiver systems. The logical "address" state of receiver 3, the clock @2 pulse and the "in tune" signal produce the required "receiver in tune with station 4" signal.

14. Each station is "addressed", in turn, by each of the four receivers and, if the frequency information compared is the same, the appropriate lamps on the instructor's station and receiver panels are lit. There are four navigational receiver panels which are located on the radio aids console (22AB, AC, AD and AE); eight STATION SELECTED lamps (1 to 8), each of which represents a station, are mounted on each receiver panel. One of these lamps lights if the associated receiver is "in tune" with a particular station; the contact sets of a relay slaved to each lamp are used in the receiver tuning discrimination system (Chap.4). On each station panel, an IN USE lamp lights when any one of the four receivers is "tuned" to a particular station. A relay coil is energized if any receiver is in tune with any station; the contact sets of this relay are used in the radio aids bearing computation system (Chap.6 and 7). The contact sets of certain relay coils which are energized when any one of the eight stations is in tune with Rx3 (NAV1) or Rx4 (NAV2), are used in the audio and inter-communication systems (Chap.5).

Individual digital logical systems

15. The automatic tuning system consists of the following individual logical systems:

(1) A two phase clock pulse generator.
(2) A ring counter, each stage of which defines the instant at which a particular station is addressed.
(3) A receiver ring counter which operates from an input provided by the output of the station ring counter, each stage of the receiver ring counter provides the address pulse which causes a particular receiver to address a particular station.
(4) A station encoding and "in tune" system, of which there are eight.
(5) A receiver encoding and "in tune" system, of which there are four.
(6) A frequency (digital) comparator which is time-shared between all stations and receiver systems.

16. The radio aids receiver tuning system (Chap.4) provides, in BCD, the frequency information, from the receiver frequency-selection controls in the cockpit to the receiver frequency encoders of the automatic tuning system; the receiver tuning discrimination system (Chap.4) determines whether two receivers are tuned to the same station and also provides a method of switching the appropriate signals when the simulated aircraft is computed to be within the small-area chart. The chart system is described in Chap.2.

Clock-pulse generation

17. The clock system is shown on drawing /307. The free-running multivibrator

21BD/T/F1 produces a clock pulse of 20μs width (waveform 1, Fig.1) with an interval between pulses of 400μs. The clock pulses are routed, via pulse-shaping amplifier 21BD/T/A1, to the NAND-gate circuit-element 21BD/T/A2, which acts as simple inverter stage; the output from /A2 is designated clock @1 (waveform 2, Fig.1). The NAND-gate /G1 acts as a simple inverter, and the positive-going edge of the waveform from its output (waveform 2, Fig.1), sets the monostable, /F2. The monostable assumes the stable state (resets) after 300μs and the positive-going edge of the monostable output (waveform 3, Fig.2) sets the second monostable, /F3. The output of /F3 is shaped by the pulse shaper /A3, the output of /A3 being designated clock @2 (waveform 4, Fig.1).

One-shot facility

18. When the NORMAL/ONE SHOT switch 21BB/S1 on the state panel (para. 47) is set to ONE SHOT, the multivibrator /F1 is converted into a monostable circuit and the monostable is reset by pressing the ONE SHOT button 21BB/S2. A single pulse of 20μs duration (waveform 1, Fig.1) is produced each time the button is pressed. The WARNING TEST lamp 21BB/LP1, on the state panel, lights via diode 21BB/MR1, when the NORMAL/ONE SHOT switch is set to ONE SHOT.

Station frequency encoding

19. The frequency encoding systems for stations 1 to 8 are shown on drawings /308 and /309. All encoding systems are identical and station 1 system is described. The contact arrangements of each decade of the six-decade binary-coded-decimal, STATION FREQUENCY selection switch /S7, (21AC/S7a to 21AC/S7f), provide electrical states which represent four bits per decade. Each decade represents the thousands, hundreds, tens, units, tenths and hundredths digits of the numerical value of station frequency selected. When each of the four contacts of an individual switch are closed (e.g., 21AC/S7f) a bit-value of 1 is represented. For example, to represent the decimal digit 3, the open/closed states of the contacts of 21AC/S7f are as follows:

(1) 2^0 closed (binary bit-value of '1')
(2) 2^1 closed (binary bit-value of '1')
(3) 2^2 open (binary bit-value of '0')
(4) 2^3 open (binary bit-value of '0').

20. The open/closed state of the contacts of the switches, to represent any selected decimal digit between 0 and 9, is determined by manual selection of the digit, and by the internal mechanical construction of the switches. There are no external connections to contacts 2^1, 2^2 and 2^3 of 21AC/S7f and, therefore, no selection of a

"thousands" decimal digit above 1 is provided. The highest value of selectable frequency is 1999·9 (kc/s or Mc/s).

21. When the station is being addressed, the supply to the station 1 frequency encoders is fed from the station system (para. 32 and 33), i.e., when station 1 is being addressed, -12V is supplied, via the closed contacts of the BCD switches, thus causing the appropriate diodes (/MR1 to /MR17) to conduct. Either 0V or -12V (logical '0' or '1') then appears on each of the frequency busbars F1 to F19, depending on the station frequency selected by the BCD switches, and on the open or closed condition of the KC/S - MC/S switch, 21AC/S5 (F19). The range of selected station frequencies is from 0 to 1999·9 (kc/s or Mc/s); selection of a digit value of one one-hundredth (·01), is also available (21AC/S7a) but is not used.

Receiver frequency encoding

22. The digital information, which provides the numerical value of the frequency to which each of the four radio aids navigational receivers is tuned, is fed (in BCD form) from the appropriate receiver tuning system (Chap.4); the coils of the encoding relays, which are located in position 22BC, are energized by the appropriate receiver tuning system. The receiver frequency encoding system is shown on drawing /310. When closed, (operated) the encoding contact sets of these relays feed, via the associated conducting diodes /MR201 to /MR250, a positive voltage which corresponds to a logical '1' (positive logic), to the receiver frequency busbars, f1 to f19. The relay table on drawing /310 lists the encoding relay coils which are energized in the associated receiver tuning system when the receiver is tuned to a particular frequency

23. Each receiver (Rx1 to Rx4) is supplied with a positive 'address' voltage from the appropriate receiver system (para. 34) which is connected to the 'commoned' normally-open (released) contact sets of the associated receiver encoding relays. Therefore, either +12V or 0V (logical '1' or logical '0') appears on each of the frequency busbars when the encoding contacts are operated, thus providing the BCD digital value which represents the receiver frequency information. The bit-values of the BCD receiver busbars which are common to all four receivers, are as follows:

(1) f1: one (2^0) (thousand)
(2) f2 to f5: eight (2^3), four (2^2), two (2^1) and one (2^0) (hundreds), respectively
(3) f6 to f9: eight, four, two and one (tens), respectively
(4) f10 to f13: eight, four, two and one (units), respectively
(5) f14 to f17: eight, four, two and one (tenths), respectively
(6) f18: 0·01 (one hundredth); this busbar is fitted but not used
(7) f19: Mc/s.

Station and receiver ring counters

24. The logical diagram of the station and receiver ring counters is shown on drawing /302. The bi-stable flip-flop circuits which comprise the individual stages of the two ring counters are connected in series, with delays of 55μs between adjacent outputs and inputs. The set output of each stage, when it represents a logical '1', determines the time at which a particular station is addressed by a receiver. The trigger-pulse for the station counter bi-stables is derived from the clock @ 1 source and is fed to each bi-stable via its associated NAND buffer amplifier circuit-element, e.g., 21BD/E/F1 and /E/G1.

25. A single logical '1' is made to circulate in the station counter at the command of the clock pulse, thus setting and resetting each bi-stable flip-flop in turn. The output from the first (/E/F1) stage of the station counter is fed as the triggering pulse (via /L/G1) to the receiver ring counter. A logical '1' is also made to circulate in this counter, and for every complete circulation of the logical '1' through the station counter, the logical '1' in the receiver counter must, therefore, progress by one stage. At any one time, only one station is addressed by any one receiver, and all station-receiver combinations are addressed once for every complete circulation of the ring counters.

26. Assuming, for convenience, that station 1 flip-flop /E/F1 is initially set, and that all other flip-flops are reset, then the first clock-pulse simultaneously resets /E/F1 and sets /E/F2, thus transferring the logical '1', previously held in /E/F1, one place to the right. The setting or resetting of the flip-flops is achieved by connecting the outputs of each flip-flop to the clock-pulse steering inputs of each succeeding flip-flop. The 55μs delays ensure that the steering inputs remain steady throughout the duration of the clock-pulse. A DM160-type indicator (e.g., 21BB/V1), mounted on the state panel, is connected to the reset output of each flip-flop. Each indicator is operated by a voltage corresponding to logical '0' and, therefore, lights to indicate the set state of the associated bi-stable.

27. The logical '1' in the receiver ring counter is passed down the counter as the result of an operation similar to that of the station counter, except that its progress to the succeeding receiver counter stages is at the command of the inverted (/L/G1) reset output from the eighth stage of the station counter.

Station ring counter resetting

28. To ensure that only one logical '1' is circulating in the station counter, the set output of the eighth flip-flop, /H/F2, is fed, via the NAND inverter amplifier /L/G2, to the resetting diodes connected to the set output of all the bi-stable flip-flops (except /E/F1) in the ring counter. When /H/F2 is set (logical '1'), the resultant

logical '0' from /L/G2 resets the other flip-flops. At this stage, two logical '1' 's might be left in the counter, i.e., in the first stage (/E/F1) and in the last stage (/H/F2). Normal circulation through the counter eventually results, however, in the setting of the seventh and eighth stages, and the resultant output from /L/G1 resets the seventh stage. When the equipment is first switched on, the counter flip-flops may assume random states which result in the "insertion" of superfluous logical "ones" into the counter; these are, eventually, eliminated by the resetting process described.

29. If, when the equipment is switched on, all the flip-flops assume the reset ('0') state, it is clear that the logical '1' which is required to circulate in the counter must be generated by the eighth stage (/H/F2). For this purpose, the set outputs of all the flip-flops are connected to an OR-gate formed by the diodes which connect the set output of each flip-flop to the input of the non-inverting amplifier /T/A4. To set the eighth flip-flop /H/F2, the output of the NAND-gate /M/G1 must be a logical '1' when the first clock pulse is applied. This output, in addition to providing the set input to /H/F2, is inverted by the single-input NAND circuit-element /M/G2, the output of which is connected to the reset input of /H/F2.

30. If, when the equipment is switched on, all the set outputs from all the flip-flops are logical '0' 's, the input to the NAND-gate diode /T3/MR3 is also a logical '0' and the input to /T3/MR2 is a logical '1' (fed from the reset output of /H/F1). The output from NAND-gate /M/G1 is then a logical '1' (para. 9) which is inverted by /M/G2 and is fed to the reset input of flip-flop /H/F2; this flip-flop therefore assumes the set state when the first clock pulse is applied. If, when the equipment is switched on, /H/F1 is in the reset state and the set output of any one of the other ring counter flip-flops is a logical '1', then both of the inputs to /T3/MR2 and /MR3 are a logical '1' and the output from /M/G1 is a logical '0' (para. 9). On subsequent application of a clock pulse, flip-flop /H/F2 either resets or remains reset if already reset. If flip-flop /H/F1 is in the set state after switch-on, then the inputs to /T3/MR2 and /MR3 are a logical '0' and a logical '1' respectively; the output of /M/G1 is, therefore, a logical '1' (para. 9) and /H/F2 is subsequently set. Although the seventh (/H/F1) and eighth (/H/F2) flip-flop stages are now both in the set state, the normal resetting output from /L/G2 resets the seventh stage (para. 28).

Receiver ring counter resetting

31. The methods used for initially clearing, and for resetting, the receiver ring counter are similar to those used in the station ring counter. The controlling flip-flop is /R/F1, the resetting inverter-amplifier is /L/G3, the OR-gate amplifier is /T/A5 and the NAND-gates which control the setting of /R/F1, are /M/G3 and /M/G4.

Station systems

32. The station systems are shown on drawings /304 and /305. All eight station systems are identical and station No. 1 is described.

33. The reset output of the first stage of the ring counter is fed to inverter amplifier 21BD/E/A1. When the first stage is set, the logical '1' (-12V) at the output of /A1 provides the address pulse to the station frequency busbars (para. 21). The trigger-pulse to four "staticisers", each of which is associated with a particular receiver, is provided by the logical '1' (-12V) at the output of the power NAND circuit-element 21BD/E/A7. Each staticiser stores a single bit and comprises a bi-stable flip-flop which is associated with a relay. The appropriate flip-flop assumes the set state if any one of the four receivers is in tune with station 1 and the relay is consequently energized; this "in tune" condition is determined by the states of the set and reset "in tune" busbars which are fed from the receiver system (para. 34) to the set and reset inputs of the relay flip-flops. The -28V supply to the relay coils is fed via the ON/OFF switch 21AC/S9 on the station panel; the contact set of each of the staticiser relays supplies the tuning indicators (lamps) on the receiver and station panels and also supplies the energizing voltage to the associated relay coils (para. 45).

Receiver systems

34. The receiver systems are shown on drawing /303. Each of the four receiver systems are identical; the ADF1 receiver (Rx1) system is described.

35. The address pulse (e_1) to Rx1 from the set output of the first flip-flop (21BD/N/F1) in the receiver ring counter is fed to the input of amplifier /A3; this amplifier converts negative logic to positive logic. The logical '1' (+12V) from the output of /A3 supplies the receiver frequency-encoding busbars (para. 22), via the instructor's FAIL switch, 22AD/S1 on the ADF1 receiver panel of the radio aids console. If a particular station is "in tune" with Rx1 (as decided by the state of the "in tune" busbar which, in turn, is determined by the output of the frequency comparator (para. 39)), the "in tune" set and reset outputs of Rx1 from 21BD/N/G6 and /G3 then assume the correct state to set the appropriate "in tune" staticiser bi-stable in the station system (para. 33).

36. The equation for the "in tune" staticiser bi-stable setting-signal is derived as follows:

(1) The inputs to NAND-gate /G2 are T (a logical '1' on the "in tune" busbar), clock @2 and e_1.
(2) The output of /G2 = $\overline{T.e_1.@2}$ and the 'set' output ('1') of the high power NAND element /G3 = $T.e_1.@2$.

37. The equation for the resetting signal to the "in tune" staticiser flip-flop is derived as follows:

(1) The inputs to NAND-gate /G5 are $\bar{\bar{T}}$ (produced by NAND-gate /G4), clock @2 and e_1.
(2) The output from /G5 = $\overline{\bar{\bar{T}}.e_1.@2}$ and the output ('1'), which is fed to the reset input of the bi-stable from high power NAND element /G6 = $\bar{T}.e_1.@2$.

38. It should be noted, that in the absence of a logical '1' on the "in tune" busbar, the "in tune" flip-flop, associated with Rx1 in the station system (para. 33), automatically assumes a reset state when the trigger (address) pulse is applied via 21BD/E/A7 (/304).

Frequency comparator

39. The frequency comparator (shown in drawing /306) compares the nineteen-bit word (eighteen bits plus the Mc/s or kc/s encoding busbar f19) representing station frequency with another nineteen-bit word representing receiver frequency. If the two words are identical, the comparator produces the "in tune" signal T. A circuit description of a frequency comparator board is given in Part 5, Chap.6G.

40. The bits which form the station and receiver frequency words are of opposite electrical polarity, i.e., the station bits are negative (logical '1') and the receiver bits are positive (logical '1'). The basic comparator circuit is shown in Fig. 2; if input A is equal to input B, then the output at the junction of the comparator resistors R1, R2 (C) is zero, and hence the output at D is also zero. The logical operation of this comparator is the same, irrespective of whether both inputs A and B are a logical '1' or whether A and B are both logical '0'.

41. Assume that the station frequency bit (negative logic) is input A (Fig. 2) and the receiver frequency bit is input B. If A = 1 and B = 0, the signal at C is negative and MR1 conducts, thus producing a negative output at D. If A = 0 and B = 1, the signal at C is positive and MR1 does not conduct. The positive output at C is, however, inverted by the inverter, and the resultant negative output causes MR2 to conduct, and thus produces a negative output at D. An output is, therefore, only produced at D if inputs A and B differ from each other.

42. The station and receiver frequency words contain nineteen bits and the basic circuit of Fig. 2 is, therefore, repeated nineteen times. Only nineteen of the twenty basic circuits shown in drawing /306 are used. In this drawing the comparator resistors are formed by the circuit-elements 21BD/J/A1, 3, 5, 7, 9, 11, 13, 15, 17, 19 and 21BD/K/A1, 3, 5, 7, 9, 11, 13, 15, 17 and 19. The inverters are 21BD/J/A2, 4, 6, 8, 10, 12, 14, 16, 18, 20 and 21BD/K/A2, 4, 6, 8, 10, 12, 14, 16, 18 and 20.

logical '0' and the relevant indicator (1 to 8) lights when the appropriate station ring counter flip-flop is set; indicator 1, 2, 3 or 4 lights when the appropriate receiver ring counter flip-flop is set. The IN TUNE indicator lights to indicate that the "in tune" busbar is energized. The NORMAL/ONE SHOT switch (para. 18), in conjunction with the ONE SHOT button (/307) provides a test facility, and when this one-shot test facility is in use, the WARNING TEST lamp lights. The single clock pulse, which is produced each time the ONE SHOT button is pressed, changes the states of the bi-stables of both ring counters at the command of the operator; any desired station/receiver "in tune" combination can be obtained by the operation of the button and the observation of the monitoring indicators.

The inputs to the comparator are fed from the station frequency busbars (F1 to F19) and from the receiver frequency busbars (f1 to f19).

43. The diodes of the comparator stages are combined to form two halves of an OR-gate (21BD/J/G1 and 21BD/K/G1) the outputs of which are commoned and fed to the inverter amplifier 21BD/T3. The output of the OR-gate is a logical zero ($\overline{T}$) only when the corresponding bits in each frequency word are the same. This signal is inverted by amplifier 21BD/T3 to produce the "in tune" signal T on the "in tune" busbar If any of the corresponding bits in the words are different, the logical '1' thus produced at the OR-gate output produces a logical '0' on the "in tune" busbar. The DM160-type IN TUNE indicator 21BB/V13, on the state panel, is lit when the OR-gate output is a logical '0' (the "in tune" busbar is then a logical '1').

Tuning indications

44. The tuning indications are shown on drawing /311. The contact sets of the "in tune" staticiser relays associated with each station and receiver feed the +28V supply to the lamps on the station and receiver panels. All tuning indication circuits are identical and only those indicators that light when station '1' is "in tune" with the ADF1 receiver (Rx1) are described.

45. When the "in tune" relay 21BD/T1/RL1 (/304) is energized (para. 33), lamp 22AD/LP1, on the receiver (Rx1) panel, is lit via contact set /RL1/1; in addition, indicator lamp 21AC/LP1, on the station '1 panel, is lit via /MR42. Lamp 21AC/LP1 is also lit, via the appropriate diode, if any receiver is in tune with station 1. Simultaneously, the slave relay coil 22BC/RL1A is energized via contact set /RL1/1; in addition, relay coil 21B/RL1 is energized via diode /MR1. Relay 21B/RL1 is energized, via the appropriate diode, if any of the eight stations is "in tune" with Rx1.

46. The contact sets of /RL1A are used in the receiver tuning discrimination system (Chap.4); the contact sets of 21B/RL1 are used in the ADF1 bearing computation system (Chap.7). Drawing /312 provides a relay table which shows the location and function of the coils and the contact sets of the relays used in the radio aids system; it includes all the relays associated with the automatic tuning system.

State panel

47. The state panel (21BB) provides monitoring facilities consisting of DM160-type indicators which are connected to the reset output ('0') from each stage of the station and receiver ring counters (/302), and to the "in tune" busbar (/306). Each indicator is numbered (1 to 8 or 1 to 4) according to the flip-flop stage of the counters which it is monitoring. The operating voltage of the indicators corresponds to a

Power supply failure

8. The 26V, 400c/s synchro excitation supply is fed to the two master (C6F) compasses, via contact sets XX/CX/RL4/1 and /RL5/1. The relays are energized from the simulated essential and main a.c. supplies via circuit breakers PH/122 (COMPASS NO.1 26VAC) and SM/14 (COMPASS NO.2 26VAC), respectively. The port compass RMI is inoperative when PH/122 is tripped; the starboard compass RMI is inoperative when SM/14 is tripped.

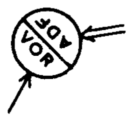
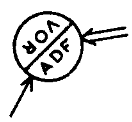
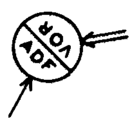
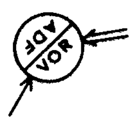
POSITION	SINGLE POINTER	DOUBLE POINTER
	VOR 1	ADF 2
	ADF 1	ADF 2
	ADF 1	VOR 2
	VOR 1	VOR 2

Fig. 1 ADF/ VOR switch positions

PART 13

SERVICING AND ROUTINE MAINTENANCE

Chapter 1

ROUTINE SERVICING

List of Contents

Introduction

1. To maintain efficiency and optimum service reliability, it is recommended that routine servicing be undertaken at regular intervals.

2. Routine servicing can be classified into two categories:

(1) Physical examination including electrical checking, mechanical inspection, cleaning and lubrication

(2) Performance checking which consists of a cycle of system checks based on information derived from the simulator acceptance schedule and, where necessary, by reference to the applicable test and setting procedures.

3. The two categories of routine servicing mentioned should run concurrently to maintain serviceability and correct functioning of individual units and adequate

simulator performance. Spare units should be available, to effect maintenance work on standard units, with minimum delays. Instructions for the servicing of the individual component parts and units are given in Chap.2.

PREVENTIVE SERVICING

Thermionic valves

4. Valves should be regularly tested during the servicing of valve-equipped units on a suitable valve tester and valves found, or suspected to be, defective should be rejected and new valves fitted.

Note...

Renewal of certain valves in standard units may necessitate re-adjustment of preset controls. Valve replacement should be done in a logical sequence to avoid random or unnecessary re-adjustments.

Semiconductor diodes

5. Semiconductor diodes should be checked only if a definite fault is suspected.

D.C. amplifiers

6. The recommended servicing procedure for the computing d.c. amplifiers consists of a sequential checking system. Two or three amplifiers are removed from the rack and replaced with spare units. The removed amplifiers are then serviced and exchanged for another two from the rack and so on. This ensures that the amplifiers in use are fully serviceable and regularly serviced.

Servos and actuators

7. The servo and actuator units require little attention. If any erratic result is noticed on the simulated aircraft instruments, the fault may be a dirty strip card in the associated servo or actuator. In this instance, the suspected card should be removed with care, cleaned and refitted. Adequate care should be taken to ensure that padding resistors and card terminal connections are not broken in the cleaning process.

Tape recorder heads

8. The tape recorder heads must be cleaned with a soft-bristled brush once a week.

Relay units

9. Apart from keeping the chassis of the relay units as clean as possible, little maintenance is required. Servicing of these units is confined to keeping the chassis as dust-free as possible and making sure that the relays are seated correctly.

Air filters

10. The air filters of the rack cooling systems should be inspected and cleaned at regular intervals to ensure consistent filtering of the cooling air. The filter servicing periods depends on local operating conditions.

PERIODIC SERVICING

11. Periodic servicing comprises the following categories:

(1) Daily checks
(2) 200-hour or monthly servicing
(3) 600-hour or 3-monthly servicing
(4) 1200-hour or 6-monthly servicing
(5) 2500-hour or 12-monthly servicing.

Daily checks

12. The daily checks are carried out in accordance with the switching-on procedure (Part 2, Chap.1).

200-hour or monthly servicing

13. The following units or systems should be checked in accordance with the appropriate setting procedure and test specification:

(1) Voltage regulator type 22G
(2) Voltage regulator type 28A
(3) ±300V unregulated power unit

(4) ±28V power units
(5) 115V, 26V 400c/s power unit
(6) -28V power unit (Advance).

600-hour or 3-monthly servicing

14. The following actuator assembly units should be checked in accordance with the appropriate setting procedure and test specification:

(1) Horizontal stabilizer (tail)
(2) Aileron trim
(3) Rudder trim
(4) Maximum ASI
(5) Flaps (Δ)
(6) Pitch ($n_1 + \alpha$)
(7) Bank (β)
(8) Incidence (α).

1200-hour or 6-monthly servicing

15. The following units should be checked in accordance with the appropriate setting procedure and test specification:

(1) M servo assembly
(2) q servo assembly
(3) Z servo assembly
(4) Four N servo assemblies
(5) All feedback (FB) and relay units.

2500-hour or 12-monthly servicing

16. The following units should be checked in accordance with the appropriate setting and test procedure:

(1) Mains regulator
(2) Velodyne resistor panels should be examined and value of resistors measured
(3) Power distribution assemblies should be examined
(4) Transformer assemblies, smoothing reservoirs, and fuse panels should be visually examined.

In addition, the complete simulator should be checked for corrosion, deterioration and structural defects.

Chapter 2

COMPONENT SERVICING

List of Contents

List of Contents (Cont'd.)

List of Tables

List of Illustrations

Introduction

1. Specified, in this chapter, are the recommended unit- and component-servicing procedures which enable the servicing personnel to maintain the simulator in an efficient state.

SAFETY PRECAUTIONS

2. All normal safety precautions, associated with the handling of units containing high tension, should be observed.

WARNING...

WHENEVER POSSIBLE, COMPONENT SERVICING SHOULD BE CARRIED OUT WITH THE RELEVANT POWER SUPPLIES SWITCHED OFF. WHERE IT IS NECESSARY FOR TESTS OR ADJUSTMENTS TO BE MADE WITH THE POWER SUPPLIES SWITCHED ON, THE GREATEST CARE MUST BE EXERCISED.

SPARES

3. Where necessary, reference should be made to the "Parts Lists" supplied with the equipment.

LUBRICATION

4. An approved list of lubricants is given in Table 1. Lubricant should be applied sparingly; excess lubrication can provide anchorage for dust and foreign matter.

5. Caged ball and roller race bearings should be cleaned as necessary with filtered white spirit and a clean soft brush. Subject the complete bearing to an air jet to remove all traces of cleaning fluid and foreign matter and apply a few drops of oil, DED 2479/0.

Note...
Bearings in synchros are lubricated on assembly. Provided that they have not become dirty or dried out, they require no further attention.

6. Uncaged ball and roller bearings should be lubricated with oil, DTD 822A.

7. For general purpose lubrication of actuators, servos and other mechanisms use oil, DTD 822A.

8. Metal gears should be lubricated with molybdenum disulphide grease, DTD 5530. Composition gears (i.e., phenolic resin etc.) should be lubricated with grease, DEF 2261. Where a metal gear is in mesh with a composition gear, lubricate both gears with grease, DEF 2261.

WARNING...
DO NOT LUBRICATE SYNCHRO GEARS.

TABLE 1

Approved lubricants

Nomenclature:	Specification:
Hydraulic oil	DTD 585
Refined mineral oil	DED 2479/0
Refined mineral oil	DEF 2101/B AM.1
Refined mineral oil	DEF 2101/B
Low temperature oil	DTD 822A
Graphited oil	-
Grease	CS 2985
General purpose grease	DEF 2261
Graphited grease	DTD 806
Low temperature grease	DTD 577
Silicone grease	DTD 897
Anti-seize grease	DTD 392
Molybdenum disulphide grease	DTD 5530

SERVICING OF ELECTRONIC COMPONENTS

PRINTED CIRCUIT BOARDS

9. The tools and materials specified in Table 2 will assist the operator to effect quick and efficient servicing of all printed circuit boards.

TABLE 2

Tools and materials for servicing printed circuit boards

Description:	Type	Quantity:
Soldering iron, 3/16 inch dia. bit, 15W	Antex No.4 or equivalent	One
Resin core solder, 60/40	Multicore PC 35	1 lb reel
$5\frac{1}{2}$ inch pointed-nose side cutters	Wilkinson 21123 or equivalent	One pair
$5\frac{1}{2}$ inch snipe-nosed instrument pliers	Wilkinson 23107 or equivalent	One pair
Small stiff-bristled brush	G.P.O. No.7 or equivalent	One
Small-bladed penknife		One
Epoxy-resin repair kit	Araldite two-tube pack	One pack

10. Printed circuit boards should, where possible, be removed from the relevant unit before servicing and placed on a clean work bench. Care should be taken to avoid mechanical damage to the boards.

11. Where a protective film has been applied to a component on the copper side of the board, it will be necessary to exert a sideways force on the component, after freeing the connecting leads or other fixing devices, to release the component from the protective film.

12. When using a soldering iron, avoid excessive heating of any soldered joint as this will reduce the strength of the bonding adhesive and also weaken the relevant section of the board.

13. It is not necessary to attempt to remove the protective varnish before applying a soldering iron to a soldered joint; the minimum heat required to melt the solder will also melt the varnish. Local repair of the damaged varnish must, however, be carried out before the printed circuit board is put into use, to prevent the ingress of moisture.

14. Three recommended methods are specified for the removal and subsequent replacement of solder-connected components from printed circuit boards. Whenever possible, method 1 should be employed.

(1) Method 1

(a) Clip off the wires close to the component that is being removed. In the case of certain non-axially wired components, it may be necessary to break the actual component in the middle before removing the component. Remove the component.
(b) Straighten the wires which are still attached to the board so that they are perpendicular to the surface of the board. Form semi-circular loops on the ends of the wires of the replacement component, so that they correspond to the spacing of the original component wires.
(c) Place the new component in position, so that the loops of the wires locate with the original wire ends, and carefully manipulate the component so that it occupies the same position, relative to the surface of the board, as the original component.
(d) Solder the loops to the protruding wires and clip off any surplus lengths of wires which remain.

(2) Method 2

Note...
This method should only be used when the appearance of the board overrides the obvious advantage of avoiding undue heating of the copper track on the underside of the board.

(a) Remove the faulty component as specified in para.14 (1) (a), and straighten the remaining wires perpendicular to the surface of the board.
(b) Clip off the wires close to the component side of the board.
(c) Apply a hot soldering iron to the soldered joint on the copper side of the board and, when the solder has melted, quickly "flick" the board to eject the wire ends, together with the melted solder, from the hole in the board. Check that there are no solder deposits remaining in the hole. Repeat the process for any other wire ends.
(d) Form the wires of the replacement component to the required shape so that they will enter the relevant holes in the board, and insert the component from the component side of the board.
(e) Ensure that the component is located on the board in the same position as the original component and, gripping the wire ends which protrude from the copper side of the board with a pair of pliers, bend the wires until they are parallel to, and in contact with, the copper pads. Remove any surplus lengths of wire.
(f) Re-solder the joints with resin-cored solder. Apply a hot soldering iron for a minimum time consistent with that required to obtain a satisfactory joint. Remove any excess resin and contaminant from the vicinity of the joint by wiping with a piece of rag which has been dipped in a suitable de-greasing agent such as trichlorethylene.

(g) Mix the components of the epoxy resin (Table 2) according to the manufacturer's instructions and apply it to those areas where the original protective varnish has been removed during soldering, taking care to overlap the old varnish. The epoxy resin will cure at normal room temperature in a few hours, but the curing rate can be accelerated if the temperature of the board is raised to approximately, but not exceeding, 50°C.

(3) Method 3

Note...
This method is recommended only when access to the faulty components, or their wires, is difficult, and where destruction of the component to gain access to the wires is impracticable.

(a) Apply a hot soldering iron to the relevant connection and, as soon as the solder has melted, remove as much of the solder as possible with a stiff brush. Repeat the procedure for any other connections.
(b) With all excess solder removed from the joint, re-apply the soldering iron and, when the solder melts, prise the wire from the joint with the blade of a small penknife or similar tool. Remove the soldering iron as soon as the wire is free. Repeat for all other wires. Check that all wires are completely free from the board.
(c) Remove the faulty component from the component side of the board, pre-form the wires of the replacement component to fit the spacing of the original holes and refit the new component.
(d) With the replacement component located in the same position as that occupied by the original component, the wire ends must be bent, trimmed and soldered, and the board re-sealed as specified in para.14 (2) (e) (f) and (g).

15. Certain components, e.g., valve bases, may be fitted on printed circuit boards with tags which may be difficult to bend without damage. Consequently, when this type of component is being removed, or replaced, any reference to bending in the previous instructions should be ignored.

Cleaning

16. All printed circuit boards must be kept as clean as possible. Because of the closely-spaced component layout which is usually adopted, any accumulated dust or grease could provide electrical conduction paths which, under certain conditions, could result in component breakdown.

17. The recommended method for cleaning printed circuit boards is as follows:

(1) Remove all dirt, grease and dust from both sides of the board with a clean brush dipped in clean trichlorethylene or similar de-greasing agent.
(2) Carefully dry both sides of the board with a suitable air blower.
(3) Replace the printed circuit board in its unit as soon as it has been cleaned and dried.

POWER SUPPLY EQUIPMENT

Mains voltage regulator

18. The Foster automatic voltage regulator, type VR/TOR, contains three identical star-connected, voltage regulator units, one for each phase. The individual units contain the following sub-units which can be serviced individually:

(1) A toroidal-wound, variable-voltage transformer (Troidac).
(2) Troidac drive motor with gearing.
(3) Series "buck and boost" transformers connected between input and output line terminals and supplied by the output of the corresponding Troidac.
(4) Electronic control unit which contains an error-voltage sensing circuit for the control of the operation of the drive motors.

19. The servicing periods depend on the conditions under which the equipment is used. The voltage-sensitive circuit detects variations in the mains supply; these error signals control, via two heavy-duty relays, the external supply to the drive motor which rotates the moving arm of the Troidac. The Troidac output increases or decreases, depending upon the direction of movement of the moving arm; this output voltage is added to or subtracted from the supply voltage via the "buck and boost" transformers. The wear of the Troidac brushes, fitted to the moving arm, is affected by frequency of operation which will depend on the fluctuation of the mains supplies and the load variations.

20. Under average operating conditions the servicing of the unit consists of:

(1) 6-monthly checks of the Troidac brushes and of the flexible cable to the moving arm.
(2) 6-monthly checks of drive motor brushes, and 5000-hour lubrication of motor bearings.
(3) 6-monthly check and sensitivity adjustment of the electronic control units.

Troidac brushes

WARNING...
PRIOR TO THE SERVICING OF THE TROIDAC BRUSHES, THE RESPECTIVE REGULATOR MUST BE ISOLATED FROM THE SUPPLY.

21. Before the brushes are removed, note carefully the manner in which the pigtail brush connections are fitted to ensure that, after subsequent brush replacement, the brush movement is free.

22. To remove the brushes, raise the spring-loaded pressure arm, which is pivoted at one end, and hold it back whilst the brushes are extracted.

23. Examine the brushes for wear and, if necessary, replace. A new brush has a parallel shank 1/8" long which is radiused in the main body of the brush. Brushes should be changed when the parallel shank has been reduced to 1/32" long; on no account should the brushes be allowed to wear until the radiused portion is in contact with the winding. Only brushes of the correct type and grade, supplied by Foster Transformers Ltd., are to be fitted.

24. All four brushes should wear equally and must be replaced at the same time.

25. Remove all dust and carbon particles from the bared portion of the winding over which the brushes travel. This surface can be cleaned with carbon tetrachloride. Abrasive material must not be used.

26. When replacing the brushes ensure that each of the four pressure pads of the pressure-equalising mechanism is seated correctly on its appropriate brush. Also ensure that the brush pigtails are positioned so that they cannot foul the fixing nuts and stems at the corners of the square Permali board on which the Troidac is mounted.

27. The Troidac will give much longer satisfactory life if it is not overloaded and the brushes are changed regularly. If the equipment is overloaded, the winding must be examined immediately and any slight burning of the track must be cleaned as described in para. 25.

28. If serious burning has occurred, or if a few turns have lifted due to over-heating, the regulator must be returned to the manufacturers. The equipment must not be used if raised turns are present as this will cause excessive wear or brush breakage.

29. After long periods, it is possible that the flexible cable from the take-off arm may become worn. This cable cannot be removed until the cable sockets on the ends

are cut off. It is important that the new cable (p.v.c. covered wire, size 110/0·0076", $16\frac{1}{4}$" long), is fitted in the same manner as the old, otherwise it may prevent the free running of the Troidac. If a crimping tool is not available, new tags may be soldered on to the ends of the cable.

Drive motor brushes and lubrication

30. Either of the following motors may be fitted:

(1) Drayton induction motor
(2) Parvalux motor.

31. The Drayton induction motor has no brushgear. The motor bearings are self-lubricating, and the motors are supplied with a grease-packed gearbox. No maintenance is required during the normal life of these motors.

32. The Parvalux motor is fitted with either self-lubricating sleeve bearings or grease-packed ball bearings, and with a grease-packed gearbox. The lubrication provided is sufficient for 5000 hours running of the motor.

33. After approximately 5000 hours running, the gearbox and end bearings, if of the grease-packed type, should be cleaned out. They should be re-packed with grease (Shell Alvania or equivalent).

34. Motor brushes should be inspected for wear after six months operation. If the wear is small after the first two six-monthly inspections, the period may be increased.

35. Access to the motor brushes is gained by removing the inspection plates at the non-drive end of the motor. To remove the old brush, lift the spring clear of the holder and withdraw the brush. Carbon brushes of the correct grade and pattern must be used.

36. At the same time as the brushes are examined, check the condition of the commutator. It should be dark brown in colour. Odd black or burnt segments indicate a faulty armature and the motor must be replaced.

37. Occasional cleaning of the commutator with a fibre-glass brush is beneficial. When new brushes are fitted, remove all carbon and copper dust, etc., from the brush gear, if possible, by compressed air.

Electronic control unit

38. The control unit is mounted on a chassis which forms a sub-assembly of the voltage regulator, and all connections are made via a multi-pin plug to allow easy removal. The main components are the input transformer T1, the motor control relays 1RL and 2RL, and two valves V1 and V2. A brief description of the operation of the unit is given in the following paragraphs; included in the description are operating voltages of the circuit. These voltages should be checked if a fault is suspected.

Note...
The electronic control unit is sensitive to the r.m.s. value of the applied voltage; therefore, all measurements should be made with a moving-iron or dynamometer type of instrument, especially if the waveform of the supplies is distorted.

39. The circuit of the unit controls the operation of the heavy-duty relays 1RL and 2RL which are fitted with heavy-duty contact sets for control of the drive motor external supply. The sequence of relay operation is given in Table 3.

TABLE 3

Sequence of relay operation

Relay:	Regulator output voltage:		
	Low:	Correct:	High:
1RL	De-energized	De-energized	Energized
2RL	De-energized	Energized	Energized
Regulator operation	Boost	Stationary	Buck

40. The relay drive circuit consists of V1 and associated components. V1 is a cold cathode trigger valve, type Z 803U, having a continuously-burning priming anode which is supplied, via resistor R10, with +130V with respect to the cathode. The anode current is cut off when the priming anode supply voltage is reduced below approximately +100V.

41. The voltage at windings 8, 9 and 10 of transformer T1 is normally 180V - 0 - 180V. This winding provides rectified control-supply to the coils of relays 1RL and 2RL, via a voltage-dropping resistor. Winding 12 and 13 supplies a 90V potential for the feed-back circuit of the unit.

42. The voltage-error sensing circuit consists of V2, which operates as a saturated diode, in series with a resistive and capacitive load. The diode emission is governed by its heater supply delivered from winding 1 and 2 of transformer T1. This emission variation is reflected in the load which, in turn, controls the trigger electrode of V1.

43. The nominal r.m.s. value of the diode heater supply is 6·3V (winding 1 and 2); the diode supply line is obtained from transformer winding 9-10 which delivers 16V. The minimum heater supply is 6V r.m.s. which gives sensitivity better than ±0·5 per cent. The heater supply can be varied up to 22V r.m.s., thus giving sensitivity of ±2 per cent, by adjustment of SENSITIVITY potentiometer R2 and VOLTAGE LEVEL potentiometer R3 (fine control) in the heater circuit of V2. Coarse adjustment in 10V steps is provided by tappings on the primary of transformer T1 and/or by selection of suitable taps on resistor R6. The heater voltage should be adjusted only after replacement of V2 to compensate for differences in valve characteristics.

44. To test or adjust the sensitivity of the unit, a variable supply, such as a hand-operated Troidac regulator is required. The variable supply has to provide only the magnetising current for the regulator under test, because the tests are, normally, made at off-load conditions.

45. The supply should be varied slowly until the motor just starts to run, first in the 'buck' direction and then in the 'boost' direction, the output voltage of the regulator being measured in each case; the difference in the readings gives the sensitivity.

46. Care should be taken not to advance the sensitivity beyond the designed figure for the particular regulator, as instability may occur. The designed sensitivity is given on the identification sheet on Page 1 of the handbook supplied with the equipment.

47. It is recommended that the sensitivity should not be set higher than is essential for the load, as high sensitivity results in unnecessary operation of the regulator and, thus, a higher rate of wear of all moving parts.

48. Normally, the positive and negative feedback potentiometers R7 and R8, which are mounted on the top of the control unit chassis, should not require adjustment. If instability is experienced, the sensitivity must be checked, as stated in para. 44 to 47, before R7 and R8 are reset.

49. If unsatisfactory motor operation is still experienced, the following adjustments may be made:

(1) If, with large error signals, the regulator 'overshoots' and then hunts, R8 should be turned slightly clockwise.

(2) If, with large error signals, the regulator stops before the error is fully corrected and then restarts. R8 should be turned slightly counter-clockwise.

(3) If, with small error signals, the regulator corrects in several steps, without overshooting, turn R7 slightly clockwise.
(4) If, with small error signals, the regulator overshoots and then hunts, turn R7 slightly counter-clockwise.

Notes...
(1) R7 and R8 interact to some extent and it may be found necessary to adjust both controls to obtain optimum results.
(2) On high speed regulators, it is not always possible to eliminate the first overshoot when correcting large changes in input voltage.

50. If V2 is changed, it may be found that the voltage level has changed and cannot be returned to the desired value by adjustment of R3. The tapped resistor R6 is provided for adjustment of level in these circumstances. R3 should be set to the middle of its range and the tapping of R6 selected to give the level nearest to that desired.

AMPLIFIER UNITS

51. Remove all dust deposits with a clean brush.

52. Examine for broken wires and damaged or overheated components. Examine the plugs for bent or broken pins. Examine the printed circuit board for raised, distorted or cracked tracks (lands).

53. All amplifiers should be tested in accordance with the appropriate test procedures detailed in Part 5.

54. Deterioration in amplifier performance is caused mainly by thermionic valve faults. Valves should be tested on a valve tester.

55. All amplifiers should be correctly zeroed before refitting them in the rack.

SERVO UNITS

56. Servo units contain velodyne motor-generator units, servo card-boxes and reduction gearboxes, and may include magnetic clutches, synchros, precision potentiometers and relays. A maximum of thirty strip-cards can be accommodated in one servo card-box.

57. The special tools and test equipment required for servo unit servicing are listed in Table 4.

TABLE 4

Tools and test equipment

Nomenclature:	Specification:
Multimeter	20 000 ohms/V f.s.d.
Servo card adjusting kit consisting of:	
Dummy strip card	
G.E.C. spring gauge	
Spring gauge extension arm	
Servo brush adjusting tool	
Spring tool assembly kit	
Plessey potentiometer adjusting key	
Special Allen keys	
Servo-box setting procedures which include the card laws (in table form) of all cards in the box	

58. Remove the complete servo unit from the rack to a clean work bench.

59. Remove the cover from the servo unit and remove the card-retainer strips. Carefully remove each card in turn.

Notes...

(1) It should not be necessary to move a card-positioning screw in order to remove a card from the box.
(2) Extreme care must be taken to ensure that card taps are not moved.
(3) Each card should be correctly marked and its correct position ensured when it is replaced in the box.

60. Examine each card for broken wires burnt resistors or bobbins, lifted contacts and dry joints, and warping.

61. Remove all dust from the box by means of compressed air or a suction cleaner. Examine the rubber end stops at the end of the box; renew if found to be unserviceable.

Note...
If the stop at the end of the box is renewed, ensure that the bridge can travel the full length of the scale after fitting the new stops.

62. Examine the card-positioning springs and renew any that are unserviceable.

63. Lightly lubricate the bridge guide rods and the bridge operating rod with grease, XG 271. Ensure that the bridge travels smoothly throughout its full operating range.

64. Examine the contact brush assemblies for wear and damage. Clean the brushes with a clean, lint-free cloth. A brush assembly should be renewed if wear has produced a groove in the brush wire to a depth equivalent to the brush wire radius.

65. Check that the brush pressure is 25 grammes ±5 grammes as follows:

(1) Run the bridge to the end of the box to allow sufficient room for the spring gauge to be used horizontally.
(2) Insert a dummy card in place of the normal card and press it down on to the brush.
(3) Set the spring gauge to 25 grammes and, with the setting tool, adjust the brush by resetting the brush plate angle.

Note...
With the top of the spring gauge probe resting on the brush wire, depress the spring gauge until either the probe or the brush moves. If the probe moves first, the pressure is too great; if the brush moves first, the pressure is too low.

66. Replace the cards in the card box in the correct order. Clean each card before it is replaced, as follows:

(1) Remove any dust from the card contact edges with a clean, lint-free cloth, then gently wipe the contact edges with a piece of clean, lint-free rag moistened with benzene and lightly coated with calcined alumina.
(2) Finally, clean with a piece of clean, lint-free rag, moistened with benzene only, to remove all the calcined alumina from the windings.

67. Refit the wiring protection plate and the card-retainer strips.

68. Examine all wiring and associated components (e.g., resistors and potentiometers) for wear, dry joints, damage and security.

69. On installation, all cards are set into their correct position and the adjusting screw is locked with a 6 B.A. nut. If the locknut has been loosened, or if a contact assembly has been changed, the following check must be made, to ensure that the card is correctly positioned, as follows:

(1) Refer to the respective card setting procedure and card law table to determine the essential setting point on the card.
(2) Connect one lead of a multimeter (set to the appropriate ohms range) to the point quoted in the table, and the other lead to the wiper tap of the card.
(3) Position the bridge to the correct scale reading, and then position the card, by means of the adjusting screw, until a minimum reading is obtained on the meter. A zero reading may not be possible due to contact resistance between the brush and the card winding.
(4) Tighten the adjusting-screw locknut and check, with the multimeter, that the setting has not been disturbed. The adjusting screw may be additionally locked by a film of varnish.

70. Close the card-box and refit the backplate.

Reduction gearboxes

71. Remove the gearbox inspection plates.

72. Examine all gears for distortion and wear, for correct alignment and mesh, and all clamping devices for security.

73. Ensure that all bearings are correctly located in their housings.

74. Lubricate metal gears, as necessary, with molybdenum disulphide grease, ZX 28.

75. Lubricate composition gears, as necessary with grease XG 271.

Note...
Where a steel gear is in mesh with a composition gear, lubricate both gears with grease, XG 271.

76. Lubricate ball and roller bearings as detailed in para.5 and 6.

77. Refit the gearbox inspection plates.

78. Remove the grease-port covers and fill the ports with grease, XG 271. Refit the grease-port covers. Lightly lubricate plain bearings with oil, OX 14.

Electrical wiring and components

79. Examine all wiring for deterioration. Ensure that it is securely strapped and clear of all moving parts. In servo units driven by a type 88X velodyne, ensure that all wiring is well clear of the motor-armature series resistors. The heat dissipated by these resistors can be sufficiently high to damage the p.v.c. insulation of any leads that might come into contact with them.

80. Check the operation of all microswitch-operating cams. Ensure that the cams are aligned so that they bear against the centre of the microswitch rollers, and that the cam clamps are secure. Service all microswitches as detailed in para.114, 115 and 116.

81. Check the operation of all clutches. Service the clutches as detailed in para.117.

82. Service all potentiometers as detailed in para.113.

83. Service all relays as detailed in para.118 to 121 inclusive.

84. Service all velodynes as detailed in para.106 to 112 inclusive.

ACTUATOR UNITS

85. Actuator units differ from servo units in that they contain an Electro-Methods motor which is capable of driving up to three (maximum) of the following components:

(1) four-ganged potentiometers (rotary type)
(2) transmitters of tele-torque synchros.

The actuator units are mounted on sub-chassis which are attached, in groups of four, to a servo-type base-plate. The actuator motors contain a gear-train, via which the precision potentiometers or synchros are driven.

86. Examine all gears for distortion and wear, for correct alignment and mesh, and all clamping devices for security.

87. Ensure that all bearings are correctly located in their housings. Bronze, oil-retaining (oilite) bearings are supplied pre-lubricated and normally require no further attention.

88. Lubricate ball and roller bearings as detailed in para.5 and 6.

89. Lubricate metal gears, as necessary, with molybdenum disulphide grease, ZX 28.

90. Lubricate composition gears, as necessary, with grease, XG 271.

Note...
Where a steel gear is in mesh with a composition gear, lubricate both gears with grease, XG 271.

91. Moving parts made from nylon or S.R.B.F. (e.g., cams, gears, etc.) should be run dry. Do not lubricate synchro gears.

92. The contact surfaces of slipping clutches should be lubricated with molybdenum disulphide grease, ZX 28.

93. Slip rings should be lightly lubricated with grease, XG 290.

94. Examine all wiring for deterioration. Ensure that it is securely strapped and clear of all moving parts. In actuator units driven by a type 88X velodyne, ensure that all wiring is well clear of the motor-armature series resistors. The heat dissipated by these resistors can be sufficiently high to damage the p.v.c. insulation of any leads that might come into contact with them.

95. Check the operation of all microswitch-operating cams. Ensure that the cams are aligned so that they bear against the centre of the microswitch rollers and that the cam clamps are secure. Service all microswitches as detailed in para.114, 115 and 116.

96. Check the engage and release operation of all clutches. Service the clutches as detailed in para.117.

97. Service all potentiometers as detailed in para.113.

98. Service all relays as detailed in para.118 to 121 inclusive.

99. Service teletorques and synchros as detailed in para.126, 127 and 128.

Vactric, A.T.L. and Electro-Methods motors

100. Vactric, A.T.L. and Electro-Methods motors should be checked as follows:

(1) Disengage the motor pinion from the follower gear.
(2) Rotate the motor shaft by hand and check that the motor runs freely without undue noise.

101. If the motor is unduly stiff or noisy, it should be removed for return to the manufacturer and a serviceable motor fitted.

Velodynes

102. Velodynes should be serviced as detailed in para.106 to 112 inclusive.

CHART RECORDER

103. Examine all chart recorder components for wear, damage and security. Clean the pen carriage guide rail with a clean, lint-free cloth and lightly lubricate with oil, OX 14.

104. Examine the pen carriage cables for fraying, damage and correct tension.

105. Clean the Rapidograph pen in warm soapy water. The manufacturer's instructions supplied with each pen show the method of dismantling. The use of ink solvent for cleaning is not recommended as some solvents are injurious to the material from which the pen is manufactured.

VELODYNES

106. All velodynes fitted in the simulator are laboratory tested and categorized 'L' or 'LS' as follows:

(1) Grade 'L' velodynes are tested to ensure that the voltage/speed characteristics are within $2\frac{1}{2}$ per cent of the true linear characteristics.
(2) Grade 'LS' velodynes are tested to ensure that the voltage/speed characteristics are within 1 per cent of the true linear characteristics.

107. An unserviceable velodyne should be replaced by a velodyne of an equivalent category. The category is marked on the outer casing of each velodyne.

108. Examine the velodyne motor and generator brushes for wear, and renew as necessary. New carbon brushes are supplied ready contoured to fit the commutator and bedding-in is not necessary.

109. Examine the commutators for wear, cleanliness and evidence of tracking. Dirty commutators can be cleaned with a fibre-glass bristled brush held lightly against the revolving commutators or, if necessary, with grade 000 glass-paper. The glass-paper should be wrapped around a flat parallel-surfaced piece of wood,

or similar material, and held in light contact with the rotating commutator. (The width of the piece of wood should not be greater than the width of the commutator). After cleaning, it is essential that all dust is removed from the commutator segments and slots by means of a stiff-bristled brush or a jet of compressed air.

110. Check with a multimeter that the resistance of the motor and generator windings is within ±10 per cent of the following values:

(1) Motor armature winding - 2·5 ohms, measured between the red and black leads.

(2) Motor field (left-hand) winding - 1250 ohms, measured between the yellow and brown leads.

(3) Motor field (right-hand) winding - 1250 ohms, measured between the green and white leads.

Note...
The motor field left- and right-hand windings are externally linked across the yellow and green leads.

(4) Generator armature - 250 ohms, measured between the red and black leads.

(5) Generator field (north- and south-pole windings) - 2000 ohms, measured between the green and yellow leads.

111. The bearings in velodyne units are pre-packed with lubricant and should not normally require further lubrication.

112. Unserviceable velodyne units should be returned to the manufacturer, suitably labelled, for repair and reclassification. The information on the label should include, if possible, brief details of the fault.

PRECISION POTENTIOMETERS

113. Examine the potentiometers and all tag connections for damage and security of attachment. Examine all leads for chafing and deterioration. Renew all suspect leads.

Notes...
(1) Do not release any potentiometer drive unless the relevant system is to be reset.

(2) Care must be exercised, when taking voltage readings at potentiometer terminals with the simulator supplies switched on, to avoid damage to the potentiometers.

MICROSWITCHES

114. Examine all rollers for freedom of rotation.

115. Examine the operating arms for signs of deterioration and ensure that the wire-retaining screws are secure.

116. Check the operation of the microswitch in conjunction with the respective cam. Adjust for positive action but ensure that, when operated, there is not excessive pressure on the operating arm, or that the pressure is increased after operation of the microswitch.

CLUTCHES

117. Examine the clutch teeth for wear.

SEMI-SEALED RELAYS

118. Servicing of semi-sealed, plug-in relays should be restricted to the following visual examination. Unserviceable relays should be removed and a serviceable relay fitted.

(1) Examine all connections and relay attachment screws for security.
(2) Check the armature for correct operation.
(3) Ensure that the relay operates correctly when the coil is energized, and check the continuity between appropriate contacts. Check for an open circuit at the appropriate contacts when the coil is de-energized. The relay base connections are shown in Fig.1.

CONTACTOR TYPE RELAYS

119. Contactor type relays contain heavy-duty, normally-open, silver contacts (rated at 28V d.c., 20A) which may become pitted or built-up with a metallic deposit during operation. When this occurs, the contacts should be refaced with an equalizing file and then burnished. Emery cloth or other forms of abrasive should not be used. The contacts should finally be cleaned with Electrolube or a similar contact cleaning agent.

120. The contact gaps can be set by adjustment of the residual screw located at the top of the relay. To adjust the contact gap, slacken the lock-nut and rotate the screw in the required direction. The contact gap setting is not critical but should be approximately 1/8 in. Tighten the lock-nut when the correct gap has been set.

121. Service each relay as follows:

(1) Examine all leads for deterioration and damage, and all connections for security.
(2) Examine all fixing screws and cable clamps for security.
(3) Carry out a continuity test, and check that each set of contacts closes and opens when the relay is operated and released. Check that the contact gap setting is correct.

The relay base connections are shown in Fig. 1.

SYNCHRONOUS CHOPPER RELAYS

122. The synchronous chopper relay type CK3 is used for signal modulating purposes in drift corrector units type DEX. Each DEX unit contains one drift corrector unit which is used in conjunction with a d.c. computing amplifier.

123. The synchronous chopper relay type CK3 is a small, plug-in unit designed to fit a standard valve holder type B9A which should be of the non-skirted type and fitted with silver-plated contacts.

124. The chopper relay is equipped with an inner contact set making electrical connection for 45 per cent of each cycle when the driving coil is energized at 6·3V a.c. 50c/s.

125. Normally, the relay does not require any servicing, but should it be necessary to adjust a stationary contact by means of the adjusting screw provided, the screening can may be withdrawn (towards the B9A base) after removing the retaining screw. Care must be taken not to damage the synthetic rubber rings. An adjustment of one side will affect slightly the setting of the other.

Note...
A quarter turn of the adjuster will change the setting by approximately 25 per cent.

SYNCHROS

126. The tele-torque form of synchro operates from a reference supply of 26V or 115V a.c., 400c/s, and is used mainly for instrument operation. In addition, the

115V a.c., 400c/s synchro, is used as a differential or as a resolver in such systems as chart recorders, radio navigation aids, etc.

127. Unserviceable synchros, and those suspected of being faulty, should be removed and serviceable synchros fitted. Unserviceable synchros should be returned to the manufacturer for repair and test.

128. Some common faults appertaining to synchros are listed in Chap.3.

TRANSISTORS

129. The following points should be borne in mind when servicing equipment containing transistors.

130. Any undue heat on, or near, a transistor could ruin the transistor. When soldering the connections to a transistor, therefore, always use a heat shunt to conduct the heat away from the transistor body. Several proprietary heat shunts are available, and all possess the advantage of being good heat conductors, light in weight and self-supporting. This latter facility enables the operator to have both hands free, which is not always possible when using a pair of pliers, for example, as a heat shunt.

131. The electrodes of a transistor (base, collector and emitter) are usually suitably identified. The method of identification depends upon the manufacturer's coding system. Always check, by reference to the manufacturer's instructions, that connections and polarities are correct before switching on the supplies.

132. When making adjustments to transistor circuits, note that a short circuit accidentally applied from the base of a transistor to the power supply, or across an emitter resistor, could cause current to flow sufficient to seriously damage, or ruin, the transistor. All test prods and tools should, therefore, be well insulated.

133. A transistor, or an associated circuit component, should not be removed from, or replaced in, a circuit unless all relevant power supplies are switched off. Surges could otherwise occur, e.g., due to the discharge of a capacitor, which could ruin the transistor.

134. Certain types of transistors can be damaged when resistance of the junctions is measured with an ohmmeter; the ohmmeter battery supply may be in excess of the transistor rating. Precautions should also be taken when using an ohmmeter to measure the resistances of a transistor circuit with power off.

135. Avoid handling transistors unnecessarily; the life of some types of transistors can be curtailed if the transistor protective coating is damaged or scratched.

136. Ensure that, as far as possible, any transistor replaced in a circuit is fitted in the position of the removed transistor and that sufficient air space is maintained around the transistor body to avoid high ambient operating temperatures.

137. Lead wires should never be bent too close to the seal which might thereby be damaged. Avoid the use of sharp-edged bending tools.

138. Adhere rigorously to any specific recommendation made by the manufacturer.

SEMICONDUCTOR DIODES

139. Semiconductor diodes should be checked only if a definite fault is suspected. The forward/reverse resistance can be determined, by use of a multimeter or similar test meter on the appropriate ohms range. Ensure that one end of the diode is disconnected from the circuit, as in this way the test instrument is not likely to suffer damage from a possible potential across the diode. A diode can be damaged by undue heat from a soldering iron, and a heat shunt similar to that used for transistors (para. 130) is recommended for use when soldering the leads of a diode, or using a soldering iron near a diode.

THERMIONIC VALVES

140. Due to the wide range of valves employed in the simulator, it is impracticable to give any specific operational valve data and it is therefore recommended that reference be made to individual manufacturer's instructions, as and when necessary. All thermionic valves should be tested on a suitable valve tester at least once during every 600 hours of operation, and any valve found to be unserviceable should be renewed immediately. The emission of a serviceable valve must not fall below 2/3 of nominal value.

PREFERRED VALUES OF RESISTORS

141. By using preferred values of resistors, and by means of a series or series/parallel connection, any desired resistance value can be obtained.

SERVICING OF MECHANICAL UNITS OF THE MOTION SYSTEM

142. The component parts of the motion system can be grouped under the following headings for servicing purposes:

(1) Motion system hydraulic power pack
(2) Hydraulic jack assemblies
(3) Motion platform.

HYDRAULIC POWER PACK

143. General servicing of the hydraulic power pack consists of a daily check for leaks, and checks of the accumulator pressure gauge reading to ensure that the accumulator is always pre-charged to half the system operating pressure, i.e., 750 lb/in^2. A weekly check should be made for leaks at pipe joints, valves, etc.

144. If a persistent leak occurs at any of the valve units, this part should be removed and the "O" ring seals checked for damage, and replaced as necessary.

145. Other than this general servicing, the following items should be checked more specifically at the intervals given:

(1) Air breather at top of tank filler cap - the gauze to be cleaned every three months
(2) Hydraulic oil DTD 585 - to be changed completely every two years
(3) Tank strainer unit - to be cleaned during oil change
(4) Return line filter unit - element to be renewed every twelve months
(5) Pump motor bearings - grease at relevant points every six months
(6) Accumulator - re-charge with nitrogen when necessary
(7) Oil level gauge - a periodic check to be made of the oil-level in the tank; the sight glass should always show full. Top up the tank as necessary.

146. All relief valves, solenoid valves, flow control valves, sequence valves, etc., should require no servicing, apart from leak checks, as already mentioned. If malfunctioning occurs at any of these items, the complete unit should be replaced.

HYDRAULIC JACK ASSEMBLIES

147. General servicing of the hydraulic jack assemblies will consist of a weekly check for leaks at pipe joints, valve, etc. If persistent leaks occur at the valve units, the "O" ring seals should be checked (para. 144). A periodic check should be made for traces of oil on the jack shafts. If a film of oil consistently occurs on these shafts, the wiper seal should be removed from the top of the jack, and renewed.

148. The following items should be checked more specifically at the intervals given:

(1) Top and bottom bearings at each jack - to be greased with heavy-duty grease XG 290 every three months
(2) Pressure line filter - elements to be renewed every six months.

149. All flow control valves, solenoid valves, relief valves, etc., should require no servicing, apart from leak checks as already mentioned; the complete unit must be replaced if any malfunctioning occurs. Dowty Moog servo valves should be replaced after every 1000 hours of running time, and returned to the manufacturer for servicing and cleaning.

MOTION PLATFORM

150. General servicing of the motion platform assembly will consist of a weekly inspection for leaks at the pipe joints on the base frame. A periodic check should be made of the tightness of all fixing bolts, particularly the attachment bolts holding the base frame to the floor. The bearings and bushes on the motion platform should be greased periodically as follows:

(1) Rubber bushes at "A" and "T" frames - to be greased with silicone grease XG 315 every three months
(2) Roll bearings at fuselage chassis - to be greased with heavy-duty grease XG 290 every three months.

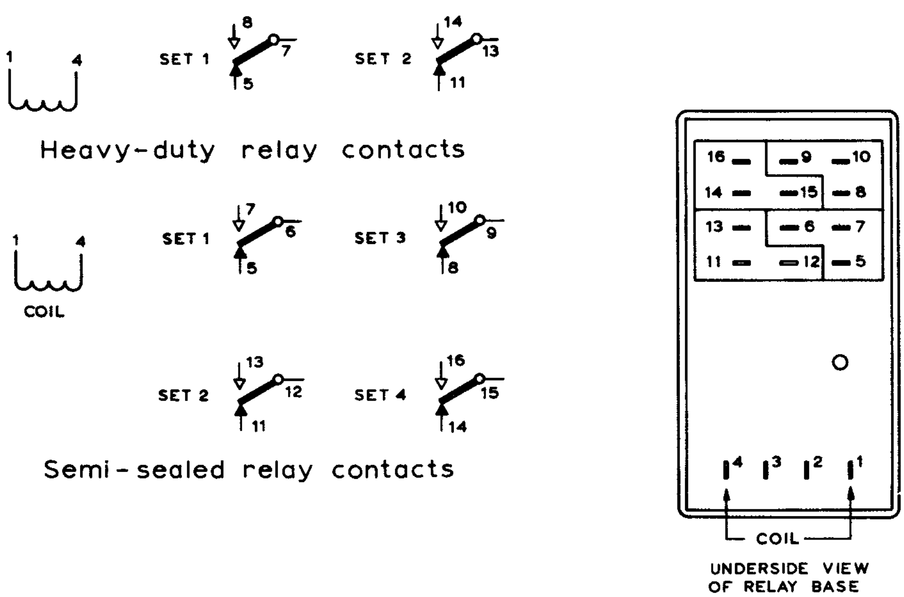


Fig. 1 Relay base contacts

Chapter 3

FAULT DIAGNOSIS

List of Contents

List of Tables

Introduction

1. Fault finding can be simplified by a thorough understanding of the systems diagrams and the component positional reference system. This enables a component or unit to be readily identified and located by means of the positional reference indicated in the system or unit circuit diagram, or the wiring data book. The positional reference system for the fuselage, cockpit, console and racks is described in the appropriate chapters of Part 1.

TEST EQUIPMENT AND SPECIAL TOOLS

2. The items of test equipment and special tools listed in Table 1, in addition to standard tool kits, are required during fault-finding and servicing procedures.

TABLE 1

Test equipment

Nomenclature:	Specification:
D.C. valve voltmeter	F.S.D. - 100mA Range - 100mV to 300V Input impedance 100M Input capacitance not more than 5pF
A.C. valve voltmeter	Range - 10mV to 250V Input impedance not less than 1M Input capacitance 30pF
Audio frequency attenuator	Range - 0 to 10dB
Multimeter	Sensitivity - 20 000 ohms/volt D.C. range - 2·5V to 500V A.C. range - 2·5V to 500V Resistance range - 1 ohm to 20M
Oscilloscope	Sensitivity - 0·1V/cm to 20V/cm Maximum input voltage - 500V Timebase - 0·1μs to 1s
Audio frequency oscillator	Range - 10c/s to 20kc/s
Variac	Range - 0 to 115V Frequency - 400c/s Rating - 1A
Voltage-divider box	4-digit decade Range - 0 to 10 kilohm Accuracy - 0·1 per cent
Voltage-divider box attachment and connector	G.P.S. Part No. B53175/A
Digital board test equipment	G.P.S. Part No. A98079/A
Valve tester	-
Stopwatch	Dial calibrated in 1/10 s
Servo card adjusting kit	Specified in Chap.2, Table 4

TEST SPECIFICATIONS AND SETTING PROCEDURES

3. The computing sections of the simulator are divided into a number of systems. Each of these systems produces one of the major functions required by the simulator.

4. Setting procedures detail the setting and testing of individual units; test specifications detail the testing of several of these units when combined to form a complete functional system (loop).

5. Test specification checks are normally carried out with the units in position in the racks so that every unit in a system is checked against all other units within that system. A check of a suspect unit in accordance with the relevant setting procedure should assist in the fault being accurately located.

FAULT FINDING PROCEDURES

WARNING...

(1) EXTREME CARE MUST BE TAKEN WHEN WORKING ON A UNIT WHERE E.H.T. AND H.T. POTENTIALS ARE PRESENT.

(2) ANY CAPACITOR WHICH IS SUBJECT TO HIGH POTENTIALS SHOULD BE DISCHARGED, VIA A SUITABLE RESISTIVE DISCHARGE PROBE, BEFORE ATTEMPTING TO REMOVE IT FROM A CIRCUIT. THE PRACTICE OF DISCHARGING A CAPACITOR TO EARTH VIA A SCREWDRIVER OR SIMILAR TOOL CAN BE DANGEROUS TO THE OPERATOR AND CAN CAUSE FAILURE OF THE CAPACITOR.

6. When commencing to trace a fault, it is advisable to make a routine check of the most likely sources of trouble. A large number of faults are caused by simple things such as:

(1) Incorrect switch settings
(2) Loose plugs or sockets
(3) Ruptured fuses
(4) Sticking relay contacts
(5) Amplifier zero switches left in the 'zero' position (switch dolly to the right)
(6) Servo auto/manual switches set to the manual position
(7) A dial knob or cursor loose on its shaft, thus giving an incorrect reading in relation to the associated potentiometer or resolver.

7. After the routine checks have been satisfied, implement the procedure given in para.8 to 11, in sequence, to locate the fault.

TABLE 1

Wiring code and sizes

Code letter:	Core size:	Voltage rating:	Current rating amperes:	Use:
A	1/0·024	750	1·75	Semi-conductor wiring (transistors other than power types). Printed circuit boards. Miniature preset potentiometers. Miniature relays (normal duty).
B	1/0·036	1000	4	Miniature relays (heavy duty).
BGy	1/0·036	1000	4	Sealed relays. Toggle switches up to 4 amperes. A.C. heater wiring (twisted pair). Internal wiring of units.
C	1/0·044	250	6	Panel wiring.
CGy	1/0·044	250	6	Rack wiring. Unit-to-unit wiring.
E	23/0·0076	1000	5	Bush-mounted potentiometers over 5 watts. Connections to hinged panels, doors, etc.
EGy	23/0·0076	1000	5	Distribution and rack wiring. Miniature relays (heavy duty). Sealed relays. Micro-switches (except miniature). Toggle switches up to 4 amperes. Components, the positions of which are adjustable. Power wiring on racks. Unit-to-unit wiring. Connections to hinged panels, doors, etc.
F	40/0·0076	1000	10	Toggle switches (4 to 7 amperes). Connections to hinged panels, doors, etc.
FGy	40/0·0076	1000	10	Rack wiring. Power wiring on racks. Unit-to-unit wiring. Connections to hinged panels, doors, etc.
J	110/0·0076	250	20	Toggle switches (7 to 20 amperes). Wiring subject to vibration.
JGy	110/0·0076	250	20	Rack wiring (general). Power wiring on racks. Unit-to-unit wiring. Wiring subject to vibration.
K	7/0·044	250	36	Rack wiring (general).

8. Ensure that the power supplies to all computer rack busbars are at the correct potentials.

9. Zero the amplifiers in the appropriate systems to eliminate any amplifier faults before proceeding to other parts of the circuit. An amplifier which cannot be zeroed correctly should be removed and replaced by a serviceable amplifier.

10. Carry out the procedure detailed in the test specification for the suspected system as an aid in locating the fault.

Note...
A fault in any particular system may also cause faults in other, related, systems. It is therefore advisable to ascertain whether any other system or circuit is also affected.

11. With the aid of the system diagram, check the signal voltages of the system inputs and outputs, the amplifier gains and signal scaling, in a step-by-step sequence until the origin of the fault is found.

WIRING FAULTS

12. When a system or unit has previously been operating satisfactorily, it is unlikely that a fault condition will be due to any wiring failure. Such defects as a dry soldered joint, disconnection at a tag or plug and open circuit in a cable can be proved by voltage or continuity checks carried out in conjunction with the wiring data books. No attempt should be made to rewire a circuit in an attempt to clear a fault.

SERVO SYSTEM FAULTS

13. A servo system tends to 'hunt' when it becomes unstable; hunting may be recognised by the oscillation of the servo motor backwards and forwards about a given position. The most likely causes of hunting in a servo system are:

(1) The gain of the driver amplifier too high due to incorrect setting
(2) Damping (tacho-generator feedback) insufficient or applied in reverse sense
(3) Incorrect field supply voltage.

SYNCHRO AND RESOLVER FAULTS

14. Unserviceable synchros and resolvers should be removed and replaced by serviceable items.

15. Typical servo faults are given in the following paragraphs as an aid to the diagnosis of synchro faults in relation to an external circuit.

Large errors

16. The receiver follows up on the transmitter, but 30 degrees or multiples of 30 degrees out of step; the most usual causes are:

(1) Reversal of wiring between synchro stators
(2) Loss of reference supply to the receiver synchro.

Small errors

17. When the receiver follows up on the transmitter in the correct sense but with an error of up to 30 degrees, and is sluggish in operation, or is inoperative over one sector, the most usual causes are.

(1) Leakage between synchro connecting leads
(2) Unbalance of resistance in the circuit between synchros
(3) Synchro windings partially shorted
(4) Receiver synchro overloaded due to an unbalanced load, high friction, or mechanical distortion
(5) Reference voltage low or frequency high, resulting in decreased energization of the synchro rotors.

Oscillation

18. Oscillation of the synchro may be caused by.

(1) Damping flywheel omitted or seized on shaft
(2) Excessive end play on shaft.

Overheating

19. The following faults can cause overheating of synchros:

(1) Reference voltage or frequency incorrect
(2) Synchro too heavily loaded, either mechanically or electrically
(3) No reference supply to receiver synchro (causing overheating of transmitter).

Noisy operation

20. The following conditions can contribute to noisy operation of a synchro

(1) Worn bearings
(2) Excessive backlash in gearing
(3) Excessive end play on rotor shafts.

Chapter 4

USE OF SYSTEM DIAGRAMS

List of Contents

List of Tables

TECHNICAL INFORMATION

1. In addition to this manual, the following technical information is supplied with the simulator:

(1) Unit and panel circuit diagrams
(2) System and unit setting procedures
(3) System and unit test specifications
(4) Servo card laws
(5) Wiring data books
(6) Feedback board assembly drawings
(7) System diagrams.

2. Circuit diagrams bear the same drawing or part number as the unit to which they refer; setting procedures and test specifications bear the same drawing number as the unit or system to which they refer. These documents are identified by suffixes to the drawing number as follows:

(1) Circuit diagrams: /01
(2) Setting procedures: /04
(3) Test specifications: /06.

3. Servo card setting procedures and servo card laws are issued with the equipment. These documents bear the same drawing or part number as the part number of the potentiometer card to which they refer, and are identified by suffixes as follows:

Card setting procedure and law: /04.

4. Wiring data books tabulate the point-to-point wiring information between units and assemblies and, with the unit circuit diagrams, provide the complete wiring data for the simulator.

5. Assembly drawings, identifiable by the suffix "/A" may be supplied for a specific unit, panel or rack assembly. A prefix letter (A, B, C, D or E) denotes the size of the drawing; e.g., B15125/A denotes a "B" size assembly drawing.

SYSTEM DIAGRAMS

6. A system diagram enables the system to be visualized as a whole, and its relevant sections seen with clarity. Signal substitution and isolation of a suspected faulty section (using the system diagram as an aid) can contribute to speedy fault diagnosis.

7. The "detached contact" system is used in system diagrams. In this system, symbols for parts of components (i.e., relay coils and contact sets, switch sections, etc.) are not necessarily placed together but are placed in positions in the diagram associated with their functional applications.

8. In addition to the circuit, the system diagram provides the following types of information:

(1) Type and rack positional reference of every amplifier
(2) The nominal value and positional reference of every capacitor, potentiometer and resistor
(3) The rack positional reference or cockpit reference of all indicator lamps, controls and instruments, (polarity of the instrument connections is normally indicated)
(4) The voltage of all supplies relating to signal or relay sources. (This is normally confined to d.c. supplies of +50V, -50V, +28V and -28V and a.c. supplies of 40V)

Note...
The system diagrams distinguish between the general 28V supplies and the radio aids 28V supplies as follows:

(a) General supplies (originating from rack 11) are designated: 27V
(b) Radio aids supplies are designated: 28V.

(5) The positional reference of all relay coils and relay contact sets (shown in the released position)
(6) The positional reference and function reference of all servo motors and servo cards
(7) The positional reference of other components such as fuses, rectifiers and switches
(8) A drawing and/or system reference at the point where the system is interconnected with another system (or other drawing)
(9) The signal scaling at pertinent points in the circuit and its designation (in terms of the equation, where applicable)
(10) A table of all relay coils and contact sets used in the system, details of their function and, where applicable, the system diagram number of any other system in which these contact sets are used.

WIRING AND CABLES

9. In general, wires and cables are colour coded as follows:

(1) D.C. signal wires	-	yellow
(2) D.C. power supply wires	-	grey
(3) Audio system and a.c. supply wires	-	multi-coloured twisted two and twisted three.

10. Table 1 details the code letters used in the wiring data books for inter-unit wiring on the simulator, and for internal wiring of individual units.

Twisted wires

11. Twisted wires are coded by prefixing the appropriate code letter listed in Table 1 with the letter T and suffixing the code letter with the number of wires in the group; e.g., TB2 is 1/0·036 twisted pair.

TABLE 1

Wiring code and sizes (Cont'd.)

Code letter:	Core size:	Voltage rating:	Current rating amperes:	Use:
KGy	7/0·044	250	36	Power wiring on racks. Unit-to-unit wiring.
N	19/0·052	660	74	Rack wiring (general).
NGy	19/0·052	660	74	Power wiring on racks. Unit-to-unit wiring.
Q	7/0·064	250	53	Rack wiring (general).
QGy	7/0·064	250	53	Power wiring on racks. Unit-to-unit wiring.
R	14/0·0076	1000	2·5	Bush-mounted potentiometers up to 5 watts. Connections to hinged panels, doors, etc.
RGy	14/0·0076	1000	2·5	Precision potentiometers up to 3 watts. Velodyne motors in actuators. Microswitches (miniature). Rotary and toggle switches. Velodyne servo motors with cable-form and plug. Synchros (twisted pair and twisted triple). Small servo motors in actuators. Rack wiring (general). Power wiring on racks. Unit-to-unit wiring. Connections to hinged panels, doors, etc.
S	14/0·0076		2·5	Audio systems wiring (screened wires).
T	7/0·0076		1·25	
U	40/0·0076		7	
V	12/0·004	750	0·75	Servo card boxes. Aircraft instruments (internal wiring). Components, the positions of which are adjustable. Connections to hinged panels. doors, etc.
W	7/0·0076	1000	1·25	Printed circuit boards. Miniature preset potentiometers. Precision potentiometers up to 3 watts. Miniature relays (normal duty). Semi-conductor wiring (transistors) other than power types. Crate wiring.

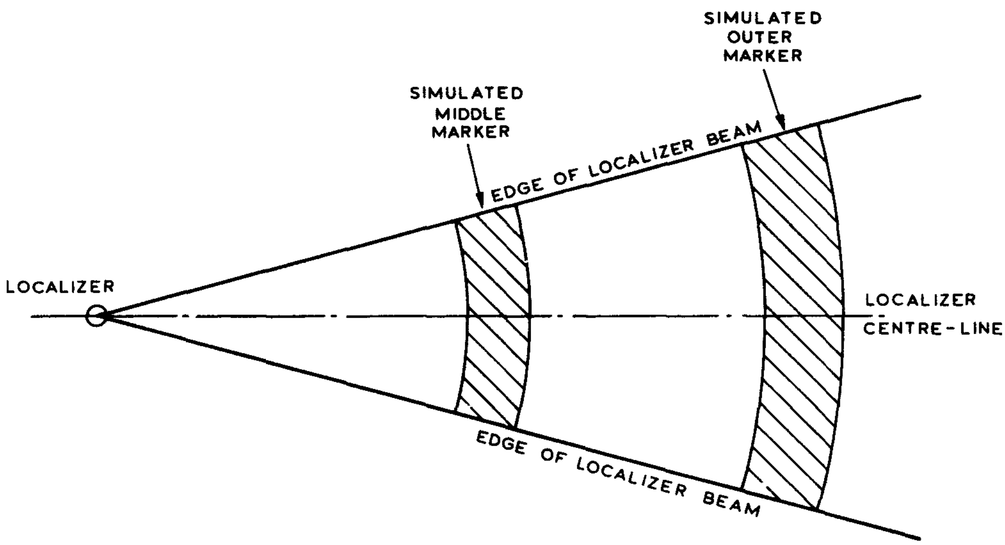


Fig 1 ILS Automatic marker reception areas