Chapter 7 AUTOMATIC CONTROLS

LIST OF CONTENTS

Introduction

1. The automatic controls on this aircraft comprise the autopilot/autostabilizer system and a separate yaw damper system; this Chapter contains a brief functional description of the two systems. The servicing diagrams associated with this Chapter and information regarding the location of components complete with a list of associated Air Publications is contained in the relevant chapter of AP 101B-1202-10A.

Modification standard

2. This Chapter includes Mod 845, 905, 1019, 1032, 1103, 1126, 1131, 1152, 1168A, 1185, 1216, 1232, 1287, 1290, 1322, 1324, 1325, 1517, 1715, 1716, 1717, 1718 and 1745.

AUTOPILOT

General

3. The Mk. 20 autopilot system on this aircraft provides autostabilization and the autopilot facilities of Mach. No. lock, heading lock and barometric height lock. The autopilot system comprises the following main units:-

Roll rate gyro unit

Pitch rate gyro unit

Yaw rate gyro unit

Autopilot computer

Pilot's control switches

Autostabilization switch panel

A detailed description of the autopilot system is in AP 112C-1900-13A.

Note...

Although the autopilot is interconnected with the radio altimeter, the original provision of a height signal for a radio height lock mode is not required and the height signal line incorporates a compensating load resistance which is fitted in the autopilot computer.

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4. Also associated with the autopilot system are four powered control units (PCU) and a height lock transducer. The PCUs are part of the flying controls system (*A P* 101B-1202-1A, *Cover* 2, *Sect.* 3, *Chap.* 6B) and can work independently of the autopilot, but in the autopilot and autostabilization modes of operation their integration with the system is sufficiently complete to justify their inclusion here. The height lock transducer obtains its power supplies from the air data system (*Chap.* 8, *this Section*) but the information it provides is fed only to the autopilot, from which functional aspect it will be discussed.

Description

Gyro units

5. The gyro units are rate gyroscopes which, together with the PCUs, assist the pilot and the autopilot in increasing the natural damping of the aircraft's short period oscillations and maintaining an optimum degree of aircraft stability. Since a rate gyro is sensitive to transient disturbances about one axis only, three identical gyros mounted in mutually perpendicular planes are employed to sense disturbances about the axes of roll, pitch and yaw.

6. The signal voltages produced by the rate gyros are fed to their appropriate channel amplifiers contained within the computer and raised to a power level sufficient to operate the electro-hydraulic actuators which form an integral part of each PCU.

Powered control units

7. Four powered control units, each consisting basically of a hydraulic tandem ram, a lever assembly and an electro-hydraulic actuator, are fitted to provide the means of moving the ailerons, rudder and tail plane. The PCUs are designed for manual operation by the pilot, with or without autostabilization, but in the autopilot modes the tail plane and aileron units only are fully integrated with the autopilot system. Manual demands operate the PCU via a mechanical linkage, but autostabilization and autopilot demand signals are fed via the computer to the actuator which, in turn, causes movement of the ram. The degree of ram movement is regulated by mechanical or electrical feed back loops on the PCU which permit faithful reproduction of the pilot's stick movements or autopilot demands at the control surface.

Height lock transducer

8. The height lock transducer, R-SN, consists of a capsule unit and a servo-operated gearbox and converts static pressure into a signal voltage representative of barometric height. A follow-up system in the transducer maintains this voltage at zero until disconnected by a signal from the computer when 'height lock' is engaged.

9. Subsequent changes in the height of the aircraft produce a voltage in the transducer which represents the change in height from the stored barometric reference datum. The signal output is fed to the computer and processed to obtain an autopilot demand signal which is a function of barometric height error and the rate of change of height error.

10. With the Type B height lock transducer fitted (Mod 1152), desired changes in aircraft altitude may be achieved in the barometric height lock mode by appropriate selection of the height trim switch (*para* 14).

Autopilot modes

11. *Height lock.* The height lock mode provides a barometric height lock to maintain the aircraft at a predetermined height. The aircraft can be either manually flown to the predetermined height and the height lock mode then engaged, or with the height lock mode already engaged the pilot can alter the aircraft height by using the height trim switch.

12. To ensure that demands are made about the trimmed position of the tail plane, a tail plane angle store in the computer retains a signal from the P C U equivalent to tail plane trim angle at the moment of engagement of the height lock mode. This is used as a reference datum for the control surface position.

13. To prevent the aircraft losing height during turns a signal, which is a function of bank angle from the M R G and reciprocal Mach No. from the air data system (*Chap.* 8, *this Section*), is calculated in the autopilot computer and causes the tail plane P C U to demand a slight nose-up attitude during turns.

14. Operation of the height trim switch (*para* 21) motors the height lock transducer height datum servo at a constant speed in a direction appropriate to the particular trim selection. Motoring the servo in this way represents a continuously changing height datum which is followed by the aircraft as a result of normal autopilot height lock operation. In view of height trim selection effecting a constant rate of change of height servo datum, the system continues to demand a corresponding rate of change of aircraft height until the height trim switch is released.

15. *Mach No. lock.* In the Mach No. lock mode the aircraft maintains a constant Mach No. during level flight, co-ordinated turns and climbs and dives. Mach No. from the air data system, elevation angle from the M R G and tail plane angle from the tail plane P C U are all stored by local follow-up circuits in the computer until engagement of the mode when the stored information becomes the reference datums for the aircraft's speed and pitch attitude.

16. Deviation from the required Mach No. results in Mach No. error signals from the air data system being fed to the tail plane P C U together with a stabilization term derived from elevation angle. As in the height lock mode it is arranged that tail plane demands take place about the trimmed position and that the angle of attack is increased during turns.

17. *Heading lock.* In the heading lock mode the autopilot will fly the aircraft on any heading selected by the pilot on the navigation display. If the aircraft deviates from a selected heading the navigation display instrument feeds error signals to the autopilot computer and these are combined with a stabilization term derived from bank angle signals from the M R G to operate the aileron P C Us. By storing the starboard aileron angle at the moment of engagement of the mode it is arranged that demand signals are made about the trimmed position. Heading lock is available only when the height lock or Mach No. lock mode is engaged.

Autopilot computer

18. The autopilot computer, R-AJ, is the main unit of the autopilot system and processes the information it receives from external reference sources to produce the demand signals required to move the ailerons, tail plane and rudder. The main sub-units of the computer include the tail plane angle, Mach No., the power amplifiers for the P C Us and the relays for switching to the various modes of autopilot operation. The computer transmits a signal to the standard warning system when the autopilot system fails or when the instinctive cut-out button is pressed. Since there is no requirement for a radio height lock mode, a compensating load resistance in the computer is connected in series with the radio altimeter height indicator (*Sect.* 8, *Chap.* 5, *this Cover*).

Note...
The circuit associated with the radio altimeter is also routed through relay X (J.B. R-AW) which is used for switching the height signal via the weapons system performance recording system (Sect. 7, Chap. 10, this Cover).

Pilot's control switches

19. Five switches on the starboard dashboard shroud panel, C-X, three switches on the throttle box (panel C-E) and two switches on the pilot's control column, C-AM, are the means whereby the pilot can engage and disengage the various facilities of the autopilot system.

20. A push-switch, Z, marked ICO RESET (instinctive cut-out reset) on panel C-X is used as the power switch for connecting the aircraft power supplies to the autopilot system. Three single-pole, 3-position switches, A, B and C on panel C-X, marked PITCH, ROLL and YAW respectively and AUTOSTABILISER, APPROACH–OFF–HIGH SPEED collectively, control the autopilot system in the

autostabilization/manual mode and a rotary switch, X, on panel C-X, comprising four microswitches, marked AUTOPILOT, OFF–MACH–HEIGHT, BARO–RADIO (RADIO not used) is used to select the autopilot modes.

Note...
When the autopilot system is inoperative a guard plate marked INOPERATIVE *is secured under the knob of the rotary switch, X (panel C-X), locking the switch in the* OFF *position.*

21. A mode is engaged by operating a push-switch, U, on panel C-E, marked AUTOPILOT ENGAGE. Also on panel C-E is the heading lock selector switch, Q, marked AUTOPILOT HEADING, ON–OFF and a single-pole, changeover, spring-returned to centre switch, P, marked HEIGHT TRIM, DOWN–UP. The height trim facility is operative when the Type B height lock transducer (*para* 10) is fitted together with a Type 3D/5708-B-8 (or later) autopilot computer.

22. The autopilot I/CUT-OUT (instinctive cut-out) switch, G, and the autopilot DISENGAGE switch, H, are both located on the pilot's grip unit. The instinctive cut-out switch is the manual safety device which, in emergency conditions, is operated to disconnect all the electrical supplies to the autopilot system, to connect a d.c. supply to illuminate the indicator window marked AP on the standard warning panel, and to initiate the operation of the standard warning system (*Cover* 1, *Sect.* 6, *Chap.* 10A) and restore the aircraft to manual control. The disengage switch, when operated, disconnects the electrical supplies to the PCUs and the computer and restores the aircraft to manual control or autostabilization/manual mode if this facility has been selected.

Indicator
23. A 3-position magnetic indicator, Y, on the starboard dashboard shroud panel, displays OFF until an autopilot mode is selected, RDY (ready) when a mode has been selected and the autopilot is ready to operate, and ENG (engage) when an autopilot mode is in actual operation. The indicator also displays OFF when autostabilization only is operating.

Safety microswitches
24. To limit the authority of the autopilot and to prevent autopilot runaway, two limit microswitches are fitted to the tail plane flying control mechanism and to each aileron flying control mechanism. When any of these switches are operated, the electrical supplies to the autopilot are switched off, restoring the aircraft to manual control and operating the standard warning system. Information concerning the location and setting of these limit microswitches is in A.P.101B-1202-1A, Cover 2, Sect,3, Chap.4B and 4D.

Power supplies
25. The autopilot computer is powered by 200 V, 3-phase, 400 Hz a.c. and 28 V d.c. The 200 V a.c. supply is fed from fuses 2A2, 2B2 and 2C2 in dist. box R-A to pins A, B and C respectively of connector 13, and 28 V d.c. is fed from fuses A9 and B9 (panel R-C) to pins B and A of connector 10. A 28 V d.c. supply for the operation of the standard warning system is routed from fuse A6 (panel R-C) via pin A of connector 6. Power supplies to the height lock transducer are routed as follows:-

With the IFIS isolation switch (*Chap.* 8, *this Section*) selected to ON and a.c. and d.c. power available at junction box R-AW, relay J in the junction box becomes energized. 115 V, 3-phase, 400 Hz supplies are then routed from connector 14 to fuses P and Q and contacts 8–9 and 11–12 of relay J, thence via sub-fuses M and N to connector 3 and the height lock transducer. Selecting the IFIS isolation switch to OFF releases relay J and disconnects the a.c. supply to the transducer.

YAW DAMPER

Description
26. The yaw damper system is an emergency system to be used as a substitute for the rudder autostabilizer mode of the autopilot. The circuit contains three main units, a yaw rate gyro, a yaw damper amplifier and an actuator. The rate gyro detects any change in the rate of yaw of the aircraft and transmits a signal to the amplifier from which further signals are sent to the actuator. The actuator is mechanically connected to the rudder control to operate the rudder and correct the initial deviation. A single-pole, on-off switch, G, marked YAW DAMPER, ON–OFF, on the starboard dashboard shroud, panel C-X, is the control switch for the yaw damper system; a.c. and d.c. power supplies complete the installation.

Yaw damper amplifier
27. The yaw damper amplifier, R-GA, is located on the starboard side of the radio bay. Electrical connections are made by Plessey Mk. 4 plugs and sockets. The amplifier is housed in a metal container and consists of a magnetic amplifier, a

dither oscillator, two relays and a distribution system of resistors and capacitors. These receive and modify the impulses from the rate gyro and transmit the resultant to the torque motor in the actuator. The d.c. and a.c. power supplies are fed into the amplifier which acts as a junction box and feeds out the power to supply the rate gyro rotor and the valve solenoid in the actuator. The dither oscillator generates 'dither' impulses at 21 Hz which are fed to the actuator for improved hydraulic control.

Rate gyro

28. The rate gyro, R-GF, operates in the yaw plane and is mounted in the radio bay; it is identical to the rate gyros used in the main autostabilizer system. Any rate of turn of the aircraft causes the rate gyro to produce a proportional electrical output which is fed to the yaw damper amplifier.

Actuator

29. The electro-hydraulic actuator, R-GB, incorporates a torque motor, a hydraulic relay valve, a solenoid-operated valve, a piston assembly and an a.c. pick-off which detects movement of the piston. The actuator is connected in series with the rudder manual input circuit so that, when the system is not in use, it forms a fixed pivot about which the rudder control operates. When the system is switched on, power is fed from the amplifier to operate the torque motor, which in turn operates the relay valve, thus allowing hydraulic fluid to move the piston. Movement of the piston is transferred to the rudder linkage and the a.c. pick-off feeds back a signal to the amplifier, which in turn cancels the supply to the torque motor when the required correction has been applied to the rudder linkage.

30. The actuator incorporates restrictors which are controlled by a solenoid-operated valve. The solenoid is energized when the system is operative to permit free movement of the restrictors and hence the piston. In practice the restrictors rest against stops in a central position. Under electrical fault or system off conditions the solenoid is de-energized to allow hydraulic fluid to force the restrictors apart and lock the piston in a central position. The design of the actuator is such that the piston locks due to inbuilt friction if the hydraulic supply fails.

Operation

31. A 115 V single-phase a.c. supply from fuse 1C4 in distribution box R-A is fed via pin A of plug No. 1 of the amplifier to T1. From this transformer supplies are fed to T2, T3, T4 and the dither oscillator. The secondary current of T2, after rectification, energizes relay B, while T3 supplies power to the rate gyro motor. The d.c. power supplies are provided from fuse C10 (panel R-C) and fed to pin D of plug No. 1 of the amplifier. When the control switch is selected to ON, a d.c. supply from fuse H11 (panel C-Q) is connected via pin F on plug No. 1 and the closed contacts of relay B to the solenoid of the restrictor valve in the actuator. Relay A is also energized and the relay contacts complete a circuit from the rate gyro to the magnetic amplifier.

32. Any tendency for the aircraft to change the rate of yaw is detected by the yaw rate gyro and a signal is passed to the amplifier. The modified and amplified signal is passed to the torque motor, which moves the piston, in turn moving the rudder to make the required correction. The a.c. pick-off arm moves with the actuator piston and feeds back a position signal to the amplifier, thereby controlling the supply to the torque motor. The piston stops when the feed back signal has cancelled the demand signal.

33. Should the a.c. supply fail when the equipment is operating, relay B will become de-energized, thus releasing relay A, also removing the d.c. supply from the actuator solenoid valve, when the restrictors will lock the actuator piston (*para* 30).

SERVICING

Function tests

34. Function tests of the autopilot and yaw damper systems are in A.P.101B-1202-4A3 and CSDE Schedule—4A3.