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DESCRIPTION

General

1. Movement of the aircraft's ailerons, elevators and rudder is effected by hydraulic components which are normally controlled by electrical means, or, in emergency, by mechanical means through cables. There is no provision for direct mechanical control. In the interests of safety, two independent flying control hydraulic systems are fitted.

2. There are three modes of control, the normal mode, the automatic flight mode, and the emergency mode.

3. In the normal mode, a damping system automatically stabilizes the aircraft in all three axes, and also co-ordinates rudder movement with movement of the ailerons and elevators. Control of the ailerons and elevators in this mode is by an electrical force transducer fitted in the control column.

4. In the automatic flight mode, the damping system is operative as in the normal mode, but aileron and elevator position is controlled by an Automatic Flight Control Sub-system (AFCS). The AFCS allows the aircraft to be controlled from the ground for automatic ground control interception (AGCI) or for automatic ground control approach (AGCA). It also provides certain pilot assist functions by holding any set course and altitude, or it may hold a set Mach number by varying the aircraft's pitch attitude. The AFCS also provides for automatic navigation by controlling the aircraft according to information fed into a dead reckoning computer by the navigator.

5. In the emergency mode, the hydraulic components for the ailerons and elevators are controlled mechanically. Yaw stabilization and rudder co-ordination are maintained by an emergency yaw damping system.

6. Pilot 'feel' at the control column is provided by the damping system in the normal mode, and by mechanical means in the emergency mode.

7. A four-way push button on the control column allows for aileron and elevator trim. There are no trimmer tabs, trim being achieved by altering the position of the entire control surfaces. To reduce elevator trim drag at high altitudes, provision is made for an automatic up deflection of both ailerons.

8. If certain flight limitations are exceeded, the system automatically changes over to the emergency mode.

DAMPING SYSTEM

General

9. Three distinct channels comprise the damping system; the pitch channel, which controls the elevators; the roll channel, which controls the ailerons; and the yaw channel, which controls the rudder.

10. The switching controls for the damper system are located on a control panel fitted in the front cockpit LH console, and on the control column. Mounted on the control panel are an ON-OFF switch protected by a guard, an ENGAGE push switch for the normal mode and an EMERG push switch for engaging the emergency mode. Note that when the ON-OFF switch is selected on, power is supplied to the damper system and the AFCS. In addition, the normal mode of operation must be selected before the emergency mode of operation can be selected. Two push switches are fitted in the control column grip. One switch, when operated, reverts the damper system to the emergency mode of operation, and the other switch, when operated, disengages the automatic flight

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mode system. Three indicator lights fitted on the master warning system panel indicate, respectively, roll and/or pitch axis disengaged, emergency yaw damping system operative and all damping inoperative.

PITCH AXIS

Command Circuits

11. The pitch axis command circuits operate in response to command signals from the control column force transducer in the normal mode of operation or from the automatic flight control subsystem (AFCS) in the automatic mode of operation. On receiving such signals the command circuits actuate the electro-hydraulic parallel servo unit and the electro-hydraulic differential servo units, and these, in turn, affect the appropriate positioning of the elevators. The operation of the command circuits is described in the following paragraphs. The hydraulic operation of the servo units is described in Service Data Ref. No. 32.

12. Force exerted on the control column handgrip results in an output voltage from the force transducer which is fitted in the control column at the base of the handgrip. The magnitude of this voltage is directly proportional to the force exerted on the control column. The phasing of the voltage depends upon the direction of the motivating force relative to the neutral position of the control column, voltages produced by motion forward being 180° out of phase with voltages produced by motion aft. Note that changes in attitude are not commanded by movement of the control column but by the application of force on the handgrip, which deflects the core of the force transducer. Movement of the control column, in effect, follows the positioning of the elevators by the command circuits, but the response of the system is so immediate that attitude changes appear to result from movement of the control column.

13. The output voltage from the transducer is approximately one volt for each six pounds of force exerted on the control column handgrip. The output of the transducer is restricted by means of adjustable mechanical stops which limit the maximum output to six volts. A pitch axis control adjustment fitted in the circuit is, however, set at present to result in a maximum output of 4.5 to 5 volts.

14. The output from the transducer is supplied via a summing network as a command signal to an integrator unit the output voltage of which increases at a rate proportional to the strength of the command signal. The rate of increase of the integrator output is such as to prevent an excessive rate of control surface movement. The integrator maintains its output even after the command signal is withdrawn, and until it is provided with a signal of opposite phase to reduce, cancel or reverse the output according to the strength of the new signal.

15. The output of the integrator is supplied through a summing network to a servo amplifier unit which amplifies the signal and determines its phase by means of a discriminator circuit.

16. From the servo amplifier the signal passes to the transfer valve of an electro-hydraulic parallel servo which controls the elevator movement in magnitude and direction in accordance with the strength and phase of the input signal. The parallel servo effects movement of the elevators via the elevator quadrant, and so a sympathetic movement of the control column takes place.

17. A self-balancing or feed-back circuit is introduced from the parallel servo to the servo amplifier. Any movement of the parallel servo output rod produces a feed-back signal opposite in phase to the initiating signal and of a magnitude proportional to the extent of the movement of the parallel servo. This feed-back signal is applied to the summing point between the integrator and the servo amplifier, where it opposes and presently nullifies the integrator output and, consequently, output from the servo amplifier. When this nullifying effect occurs, movement of the parallel servo, and therefore of the elevators, ceases.

UNCLASSIFIED

18. The system is designed, by the provision of a normal accelerometer and air data transducer components, to produce a given 'g' loading in response to a given force applied to the control column handgrip, independent of airspeed and altitude. The normal accelerometer provides an output signal of one volt per 'g' of loading in the pitch axis. This signal is 180° out of phase with the command signal from the transducer, so that when the aircraft commences a manoeuvre imposing a 'g' loading, the resulting output of the normal accelerometer progressively nullifies the command signal. The command signal is also modified by the air data transducer components to compensate for changes in airspeed and altitude. Thus, since the transducer output signal is proportional to the applied force and the accelerometer output signal is proportional to 'g' loading, the force that must be applied to the control column handgrip to produce a manoeuvre of a given 'g' will be constant, regardless of airspeed and altitude.

19. As described above, force exerted on the control column in a fore or aft motion relative to the neutral position will produce elevator movement in proportion to the applied force, and the elevator movement will cease when the integrator output is balanced by the feed-back signal from the parallel servo. Meanwhile the resultant 'g' loading will have produced an accelerometer signal to nullify the signal from the transducer, and the system will remain balanced until a new command signal appears. If the force exerted on the handgrip is reduced to zero the signal from the accelerometer is no longer opposed by a signal from the transducer amplifier and therefore acts as a new command signal. Being of equal strength but of opposite phase to the original command signal, its appearance at the integrator input results in the cancelling of the integrator output. The feed-back signal from the parallel servo thereupon finds itself unopposed and returns the parallel servo and therefore the elevators and the control column to a position where the 'g' loading is removed from the axis.

20. A slight time lag occurs between the receipt of a signal by the integrator and the subsequent output by the integrator of a signal to the servo amplifier. While this delay has a useful effect in preventing the transmission to the control column via the parallel servo of short-term corrective movements of the elevators (see paras 23 through 26), it would also have the undesirable effect of delaying the response of the elevators to command signals but for the action of the differential servos. Command signals which are fed to the integrator are also fed to the two differential servos connected into the elevator control linkages. These electro-hydraulic units operate the elevators immediately in response to the command signals. Elevator movement is then taken over by the parallel servo as output becomes available from the integrator. As the command signal circuit to the differential servos does not incorporate an integrator, the differential servos return to their original position as soon as the command signal is nullified by the action of the accelerometer. This allows them to return to their main task of damping uncontrolled movements about the pitch axis as described in paras 23 through 29.

21. The operation of the command circuits under command signals from the AFCS in the automatic mode of operation is identical with that in the normal mode. In the automatic mode the command signal from the AFCS substitutes for the signal from the transducer.

22. Selecting the landing gear down introduces certain changes in the command circuits. The main effects of such action are to interrupt the command circuit to the differential servos and to prevent the accelerometer output and the airspeed compensation from acting upon the command signal, which is supplied directly to the parallel servo amplifier, by-passing the integrator. These command circuit changes are effected by two fader units and result in elevator movement becoming directly proportional to control column movement without regard to airspeed and altitude. Other effects resulting from selecting the landing gear down are the re-routing of the attitude trim circuit through a point immediately preceding the integrator instead of through the trim motor (see paras 34 and 35), and the shorting out of the integrator in the pitch rate gyro circuit (see para 29).

Sensing Circuit

23. A pitch rate gyro is incorporated in the system as a sensing device to correct

uncontrolled movement about the pitch axis. On detecting movement the gyro produces a signal which is proportional to the rate of pitch, rather than to aircraft displacement, so that comparatively quick corrective action can be achieved automatically before the displacement becomes significant.

24. The output signal from the gyro is supplied to the circuits of the differential and parallel servos to correct the uncontrolled movement and maintain stable flight.

25. In order to prevent signals from the pitch rate gyro from opposing command signals for pitch changes, an integrator is incorporated in the sensing circuit the function of which is to nullify output signals from the gyro resulting from steady state attitudes of climb or dive about the pitch axis.

26. Signals resulting from movement of the aircraft about its pitch axis at a rate of 4 cps or more are referred to as short term signals. Signals produced by movement of less than 4 cps are called long term signals. An operating time lag in the gyro circuit integrator prevents the nulling out of short term signals, which are supplied only to the differential servos. It also permits long term signals to appear in the differential and the parallel servo circuits, thus initiating corrective movements of the servos. Movement of the parallel servo produces sympathetic movement of the control column via the mechanical linkage of the elevator quadrant so that the balance of the command circuit is maintained. Corrections applied by the differential servos, however, do not produce movement of the control column, the mechanical linkage of the hydraulic jack acting to prevent such an effect. See Service Data Ref. No. 15.

27. Short term signals resulting from movements exceeding 4 cps about the pitch axis effect the operation of the differential servos only. These signals are not supervised by the gyro circuit integrator because of its operating time lag, and, for the same reason, they do not affect the parallel servo integrator. Thus short term signals are effectively blocked out of the parallel servo circuit where they would produce undesirable control column reactions. The differential servos are positioned continuously by the short term signals to correct short term movements automatically and maintain stable flight.

28. When a corrective movement is initiated and the aircraft commences to return to its original attitude, the signal produced by the gyro will be of the opposite phase. In the case of short term movement, the differential servos will then be moved in the opposite direction, positioning the elevators to limit the correction. In the case of long term movements, the signal cancels the output of the parallel servo integrator, thus permitting the servo feedback signal to operate the amplifier and return the elevators to the neutral position.

29. When the landing gear is selected down and the command circuits are operative as described in para 22, the gyro circuit integrator is shorted out. In this condition steady state pitch rate signals, in addition to long term and short term signals, are supplied to the differential servos. This action aids stability in the pitch axis at low airspeeds.

Trim Circuits

30. Three trim circuits are incorporated in the pitch axis damper channel, viz. an attitude trim circuit, a pressure trim circuit and an artificial feel circuit.

Attitude Trim Circuit

31. The attitude trim circuit can be used to trim the aircraft into a climb or dive. The circuit is controlled by the trim switch on the control column grip. Operating the trim switch provides a power supply to a motor-positioned potentiometer incorporated in the trim unit. The voltage picked off this potentiometer is supplied to the summing point of signals from the

UNCLASSIFIED

normal accelerometer and signals from the force transducer or the AFCS. The trim signal operates in the command circuits in the same way as does a command signal.

32. When the trim switch is operated, the movement of the aircraft about the pitch axis produces signals from the rate gyro and the normal accelerometer. The signal from the pitch rate gyro being a steady state signal is nullified by the integrator. Note that, due to the inability of the integrator to follow, short term signals continue to be provided by the pitch rate gyro to the differential servos. The output of the normal accelerometer nullifies the trim signal with the same results as when a command signal is nullified. Until the trim switch is again operated, transducer signals will add to or subtract from the standing signal from the trim potentiometer to effect further movement of the elevators.

33. When the pitch axis damper channel is disengaged, the trim switch will govern the feel and trim unit of the artificial feel circuit instead of the attitude trim circuit. See para 43.

34. When the landing gear is selected down, the power supply from the trim switch is supplied directly to the parallel servo integrator. This prevents the normal accelerometer and the air-speed compensation from acting on the trim signal, these functions being by-passed in the command signal circuits.

35. The output of the integrator is supplied to the summing point of command signals from the force transducer and the parallel servo feed-back circuit. The trim signal will effect movement of the parallel servo until the circuit is balanced by the feed-back signal. Subsequent command signals will then add to or subtract from the standing trim signal to effect further movement of the elevators.

Pressure Trim Circuit

36. The pressure trim circuit is operative automatically when the pitch axis channel of the damper system is disengaged. The function of the circuit is to simulate command signals relative to the position of the elevators. These signals are supplied to the input of the integrator. By this means, when the system is re-engaged, the output of the integrator will correspond with the output of the control column force transducer thus ensuring smooth re-engagement.

37. The operation of the circuit is such that during emergency mode operation, the normal feed-back signal produced through movement of the output rod of the parallel servo will continue to be applied to the summing point preceding the servo amplifier. This signal will effect the operation of the amplifier and in turn the transfer valve of the parallel servo. Note that in the emergency mode of operation, action by the transfer valve does not influence the output rod, which is not subjected to hydraulic pressure during emergency mode operation. See Service Data Ref. No. 32. The operation of the transfer valve results in a pressure differential between the two hydraulic metered supply lines. This action moves a pressure sensing ram which is connected to the core of a trim transformer. The signal from the trim transformer is supplied to the integrator which provides an output signal to nullify the feed-back signal. Due to the inherent time lag of the integrator a portion of the trim transformer signal by-passes the integrator to speed response. See also Disengage Circuits, para 48.

38. Incorporated in the trim circuit feed-back transformer assembly are two switches. One switch completes the supply circuit to the feel and trim unit of the artificial feel circuit. See para 41. The other switch functions to prevent the channel engaging if the elevators are moving.

Artificial Feel Circuit

39. The purpose of the artificial feel circuit is to prevent a sudden change in feel at the control column if the pitch axis damper channel dis-engages.

UNCLASSIFIED

40. The artificial feel circuit consists of an artificial feel and trim unit which comprises an electrically operated actuator and a spring. Operating the actuator increases or decreases the load on the spring dependent upon the direction of rotation of the actuator. One end of the unit is attached to the aircraft structure. The other end is attached to the elevator quadrant, adjacent to the point of attachment of the parallel servo.

41. Exerting a force on the control column closes a switch which completes a circuit from the actuator to the parallel servo. When the parallel servo operates to execute the command signal the trim actuator receives a power supply. This action increases or decreases the loading of the spring according to the position of the quadrant. If the pitch axis damper suddenly reverts to emergency, the trim unit ensures that the load required on the quadrant by the cables from the control column balances the load that was being imposed on the quadrant by the parallel servo.

42. An additional switch is fitted in parallel with the control column switch to serve as a safety precaution against overstressing the airframe should an automatic mode failure occur. This second switch opens when the normal acceleration exceeds $\pm$ 0.5 'g' from the straight and level flight condition of 1 'g'. Therefore, 'g' in excess of this figure applied by the automatic mode is against the feel spring. Consequently, if an automatic mode failure or disengagement occurs the feel spring re-asserts itself and reduces the 'g' loading imposed by the elevators to 0.5 'g' or less.

43. The feel and trim unit serves also to trim the elevators via movement of the elevator quadrant when the damper channel is disengaged. The actuator in this condition is controlled by the control column trim actuation switch which is transferred automatically from the position trim motor to the trim actuator upon disengagement of the damper channel.

44. In the event of a seizure in the feel and trim unit, movement of the elevator quadrant would not be possible. To meet this contingency, a release circuit is incorporated in the feel and trim unit linkage to the quadrant. The circuit comprises a control switch fitted in the front cockpit and a solenoid, the plunger of which is attached to a link pin in the feel and trim linkage to the quadrant. Operating the switch energizes the solenoid which extracts the link pin. This action permits the feel and trim unit to pivot freely with movement of the quadrant. The release circuit supersedes a shear pin fitted on the first aircraft.

Disengage Circuits

45. The pitch axis disengage circuit operates automatically if the normal acceleration exceeds 5.0 - 5.5 'g'. The circuit is controlled by an electronic 'g' limiter which, when operated, completes supply circuits to the differential servos centering circuit and the parallel servo disengage circuit. See Service Data, Ref. No. 32. Note that the power supply to the damper system components is uninterrupted in the emergency mode.

46. The pitch axis disengage circuit also operates if the yaw axis monitor acts due to excessive skid, sideslip or transverse acceleration.

47. Operation of the disengage circuits reverts the channel to the pre-engage condition and illuminates the R-P AXIS indicator light on the master warning system panel. In the pre-engage condition the pressure trim circuit is operative, and the attitude trim actuation switch is transferred to the trim actuator of the feel trim circuit.

48. When the channel is in the pre-engage condition the output of the force transducer, the normal accelerometer and the pitch rate gyro is routed to the trim unit to ensure smooth re-engagement. A trim unit amplifier, fitted in the circuit immediately preceding the trim unit, discriminates upon the phase of the applied signals to effect the proper direction of rotation of the motor-driven potentiometer of the trim unit. The effect of this provision is such that any unbalanced signals appearing in the command circuit initiate the operation of the trim unit

UNCLASSIFIED

and are balanced out by the resulting output signal from the trim unit. This ensures that the channel will be re-engaged into a balanced circuit and, as described in paras 36 and 37, in agreement with the prevailing position of the elevators. But for this provision, an unbalanced signal, resulting for example from failure of the gyro circuit integrator to nullify a pitch rate signal, would produce unexpected and undesirable movement of the elevators.

49. Note that if an unbalanced signal is being nulled by the trim unit when re-engagement occurs, the effect is equivalent to introducing an out-of-trim condition on the axis. This is due to the trim signal standing at the summing point of signals from the force transducer and normal accelerometer. In this condition, to regain level flight with the control column in neutral, the trim actuation switch must be operated to cancel the trim signal.

ROLL AXIS

Command Circuits

50. The roll axis command circuits operate in response to command signals from a force transducer in the normal mode of operation or from the Automatic Flight Control Sub-system (AFCS) in the automatic mode of operation. On receiving such signals, the command circuits actuate an electro-hydraulic parallel servo unit and two electro-hydraulic differential servo units which effect the appropriate positioning of the ailerons. The operation of the command circuits is described in the following paragraphs. The operation of the electro-hydraulic servo units is contained in Service Data Ref. No. 32.

51. In order to reduce elevator trim drag at high altitude, both ailerons are deflected up when the aircraft reaches a pressure altitude of 45,000 feet. This is done by an actuator fitted on the aileron quadrant in such a manner that it rotates a cam which drives the quadrant levers apart. The actuator is controlled by a pressure switch adjusted to close and complete the actuator supply circuit at 45,000 feet. To provide an operating differential, the switch is adjusted to re-open at 42,000 feet. The operation of this circuit does not affect the positioning of the ailerons by the damper system.

52. Force exerted on the control column handgrip in a left or right motion, produces an output voltage from the force transducer which is fitted in the control column at the base of the grip. The magnitude of this voltage is directly proportional to the force exerted on the handgrip. The phasing of the voltage depends upon the direction of the motivating force relative to the neutral position of the control column, voltages resulting from left motion being 180° out of phase with voltages resulting from right motion. Note that changes in attitude are not commanded by movement of the control column but by the application of force on the handgrip, which deflects the core of the force transducer. Movement of the control column, in effect, follows the positioning of the ailerons by the command circuits, but the response of the system is so immediate that attitude changes appear to result from movement of the control column.

53. The roll rate produced is proportional to the output voltage from the transducer, 0.05 volt output producing unit rate of roll. The maximum output of the transducer is limited by means of mechanical stops to six volts with a force of 20 lb exerted on the handgrip, which produces a roll rate of 120 degrees per second. A roll axis adjustment control is fitted in the circuit so that the output of the transducer may be preset.

54. The resulting output from the transducer is supplied via a summing network as a command signal to an integrator unit the output voltage of which increases at a rate directly proportional to the strength of the command signal. The rate of increase of the integrator output is such as to prevent an excessive rate of control surface movement. The integrator maintains its output even after the command signal is withdrawn, and until it is provided with a signal of opposite phase to reduce, cancel or reverse the output according to the strength of the new signal.

UNCLASSIFIED

55. The output of the integrator is supplied through a summing network to a servo amplifier unit. This unit, in addition to its function of amplifying signals, incorporates a discriminator circuit to determine the phasing of the applied signal.

56. From the servo amplifier the signal passes to the transfer valve of an electro-hydraulic parallel servo which controls the aileron movement in magnitude and direction in accordance with the strength and phase of the input signal. The parallel servo effects movement of the ailerons via the aileron quadrant, and so a sympathetic movement of the control column takes place.

57. A self-balancing or feed-back circuit is introduced from the parallel servo to the servo amplifier. Any movement of the parallel servo output rod produces a feed-back signal opposite in phase to the initiating signal and of a magnitude proportional to the extent of the movement of the parallel servo. This feed-back signal is applied to the summing point between the integrator and the servo amplifier, where it opposes and presently nullifies the integrator output and, consequently, output from the servo amplifier. When this nullifying effect occurs, movement of the parallel servo, and therefore of the ailerons, ceases.

58. The system is designed, by the provision of a roll rate gyro and air data transducer components, to produce a given rate of roll in response to a given force applied to the control column handgrip almost independent of airspeed. The roll rate gyro provides an output signal of 0.05 volt per unit rate of roll. This signal is 180° out of phase with the command signal. The command signal is also modified by the air data transducer components to compensate for changes in airspeed. The compensation function is preset to result in a decrease of gain at the extremes of low and high airspeeds and is constant for all other airspeeds. This action aids stability in the roll axis by limiting over-control by the ailerons. Thus, since the transducer output signal is proportional to the applied force and the roll rate gyro output signal is proportional to the rate of roll, the force that must be applied to the control column handgrip to produce a manoeuvre of a given roll rate is constant, except at high and low airspeeds when the force to produce a given rate of roll is increased.

59. As described above, force exerted on the handgrip in a left or right motion relative to the neutral position will produce aileron movement in proportion to the applied force, and the aileron movement will cease when the integrator output is balanced by the feed-back signal from the parallel servo. Meanwhile the resultant roll rate will have produced a roll rate gyro signal to nullify the signal from the transducer, and the system will remain balanced until a new command signal appears. If the force exerted on the handgrip is reduced to zero, the signal from the roll rate gyro is no longer opposed by a signal from the transducer amplifier and therefore acts as a new command signal. Being of equal strength but of opposite phase to the original command signal, its appearance at the integrator input results in the cancelling of the original signal there and, consequently, in the cessation of integrator output. The feed-back signal from the parallel servo thereupon finds itself unopposed and returns the parallel servo and therefore the ailerons and the control column to a position where the roll rate is zero.

60. A slight time lag occurs between the receipt of a signal by the integrator and the subsequent output by the integrator of a signal to the servo amplifier. While this delay has a useful effect in preventing the transmission to the control column via the parallel servo of short-term corrective movements of the ailerons (see paras 65 and 66), it would also have the undesirable effect of delaying the response of the ailerons to command signals but for the action of the differential servos. Command signals which are fed to the integrator are also fed to two differential servos connected into the aileron control linkages. These electro-hydraulic units operate the ailerons immediately in response to the command signals. Aileron movement is then taken over by the parallel servo as output becomes available from the integrator. As the command signal circuit to the differential servos does not incorporate an integrator, the differential servos return to their original position as soon as the command signal is nullified by the action of the roll rate gyro. This allows them to return to their main task of damping uncontrolled movements about the roll axis as described in paras 63 through 67.

UNCLASSIFIED

61. The operation of the command circuits under command signals from the AFCS in the automatic mode of operation is identical with that in the normal mode. In the automatic mode the command signal from the AFCS substitutes for the signal from the transducer.

62. Selecting the landing gear down introduces certain changes in the command circuit. One effect of this action is to prevent the roll rate gyro signal and the airspeed compensation from acting upon the command signal. In this condition, the command signal is supplied directly to the parallel servo amplifier. Consequently, movement of the ailerons is directly proportional to control column movement as opposed to airspeed.

Sensing Circuit

63. In addition to its function in the command circuit, the roll rate gyro functions as a sensing device to detect uncontrolled movement about the roll axis. Since the gyro output signal is proportional to rate of roll rather than to aircraft displacement, comparatively greater control of the ailerons can be achieved automatically before the displacement becomes significant.

64. The output signal from the gyro is supplied to the circuits of the parallel and differential servos to correct uncontrolled movement and maintain stable flight.

65. Signals from the rate gyro resulting from movement exceeding 4 cps about the axis are defined as short term signals and effect the operation only of the differential servos. The short term signals are effectively blocked out of the parallel servo circuit due to the operating time lag of the parallel servo integrator. The differential servos are positioned continuously by the short term signals to suit stability requirements. Corrective movements of the differential servos will not effect movement of the control column.

66. Long term signals resulting from movement of less than 4 cps about the axis are supplied to the differential servos and the parallel servo. The corrective movement of the parallel servo will effect a movement of the control column via the mechanical linkage of the aileron quadrant. This action ensures that the balance of the command circuit is maintained.

67. When a corrective movement is initiated and the aircraft commences to return to its original attitude, the signal produced by the gyro will be of the opposite phase. In the case of short term movement, the differential servos will then be moved in the opposite direction, positioning the ailerons to limit the correction. In the case of long term movements, the signal cancels the output of the integrator, thus permitting the servo feed-back signals to operate the amplifier and return the ailerons to their original position.

Trim Circuits

68. Two trim circuits are incorporated in the roll axis damper channel, viz. an attitude trim circuit and a pressure trim circuit. When the channel is in the pre-engage condition, a trim actuator is operative in lieu of the attitude trim.

Attitude Trim Circuit

69. When the roll axis damper channel is engaged the attitude trim circuit is used to trim the aircraft by deflecting the ailerons. The circuit is controlled by the trim switch on the control column handgrip. Operating the trim switch drives a motor-positioned potentiometer incorporated in the trim unit. The voltage picked off this potentiometer is supplied to the summing point of signals from the rate gyro and signals from the force transducer or the AFCS. The trim signal operates in the command circuits in the same way as does a command signal.

70. When the trim switch is operated, the movement of the aircraft about the roll axis

produces a signal from the roll rate gyro. This signel nullifies the trim signal with the same results es when a commend signal is nullified. Until the trim switch is agein opereted, trens-ducer signels will add to or subtrect from the standing signal from the trim potentiometer to effect further movement of the eilerons.

71. When the roll axis chennel is disengeged, the trim switch will govern e trim unit in-steed of the ettitude trim circuit.

72. The trim unit serves to trim the eilerons vie movement of the eileron quedrent. The unit comprises en electrical sctuetor end e spring. One end of the unit is atteched to the eircrsft structure. The other end is etteched to the aileron quedrent. When the trim switch is operated the trim ectuetor increases or decreases the loeding on the spring so effecting movement of the elevetor quedrent.

Pressure Trim Circuit

73. The pressure trim circuit is operetive eutometicelly when the roll axis ohennel of the demper system is disengaged. The function of the circuit is to simulete commend signels rele-tive to the position of the eilerons. These signels ere aupplied to the input of the integrator. By this meens, when the system is re-engeged, the output of the integretor will correspond with the output of the control column force trensducer and will ensure smooth re-engegement.

74. The operation of the circuit is such that during emergency mode operetion, the normal feed-back signel produced through movement of the output rod of the perellel servo will continue to be applied to the summing point preceding the servo amplifier. This signel will effect the operation of the amplifier end in turn the trensfer velve of the perallel servo. Note that in the emergency mode of operetion, ection by the trensfer valve does not influence the output rod, which is not subjected to hydreulic pressure during emergency mode operation. See Service Data Ref. No. 15 . The operation of the trenafer valve results in a pressure differentiel be-tween the two hydreulic metered supply lines. This ection moves e pressure sensing rem which is connected to the core of e trim transformer. The signal from the trim transformer is supplied to the integretor which provides en output signel to null the feed-beck signel. Due to the in-herent time lag of the integrator a portion of the trim trensformer signal by-pesses the integ-rator to speed control response. See also Disengage Circuits, peras 77 and 78.

Disengege Circuits

75. The roll exis chennel disengege circuits operete eutomatically if the roll rete exceeds 159 degrees per second. The circuits are controlled by a roll rete disengage eccelerometer which at the predetermined roll rate limit completes supply circuits to the differential servos cent-ering circuit end the perellel aervo disengage circuit. See Service Dete Ref. No. 15. Note thst the power supply to the demper system components is uninterrupted in the emergency mode.

76. The roll axia disengage circuit will also operete if the yaw axis monitor operetes due to excessive skid, aideslip, or trensverse eccelerstion.

77. Operetion of the disengage circuits reverts the chennel to the pre-engage condition end illuminates the R-P AXIS indicator light on the mester werning system panel. In the pre-engage condition, the pressure trim circuit is operetive end the ettitude trim ectuation switch is transferred to the eileron trim circuit.

78. When the chennel is in the pre-engege condition the output of the force trenaducer end the roll rate gyro is routed to the trim unit to ensure smooth re-engegement. A trim circuit emplifier, fitted in circuit immedietely preceding the trim unit, discriminetes upon the phes-ing of the applied signals to effect the proper direction of rotetion of the motor-driven potentiometer of the trim unit. The effect of this provision is such that eny unbalenced signals

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appearing in the command circuit initiate the operation of the trim unit and are balanced out by the resulting output signal from the trim unit. This ensures that the channel will be re-engaged into a balanced circuit and, as described in paras 73 and 74, in agreement with the prevailing position of the ailerons. But for this provision, an unbalanced signal, resulting, for example, from failure of the gyro circuit integrator to nullify a roll rate signal, would produce unexpected and undesirable movement of the ailerons.

79. Note that if an unbalanced signal is being nulled by the trim unit when re-engagement occurs, the effect is equivalent to introducing an out-of-trim condition on the axis. This is due to the trim signal standing at the summing point of signals from the force transducer and normal accelerometer. In this condition, to regain level flight with the control column in neutral, the trim actuation switch must be operated to cancel the trim signal.

YAW AXIS

General

80. The yaw axis channel of the damper system corrects yawing motion and provides for co-ordinated rudder movement in manoeuvres as necessary.

81. The channel incorporates two independent systems. One system is operative in the normal mode of damper system operation. The other system is operative only in the event of the normal system disengaging, i.e. in emergency mode operation. Except that a circuit is deleted in the emergency mode, both systems are identical in operation. The effect of the deleted circuit is to restrict the rudder co-ordination to manoeuvres of normal flight.

82. No independent command signals are supplied to the yaw axis channel in either the normal mode system or the emergency mode system. The motivating signals are provided by sensing devices which operate automatically in particular attitudes of the aircraft. These signals are, in most instances, consolidated at various summing points and the resultant supplied to a servo amplifier.

83. Signals applied to the amplifier are amplified to a usable level and the phasing discriminated against a reference. The output of the amplifier initiates the operation of a rudder dual differential servo valve which in turn operates the rudder hydraulic jack control valve to cause the deflection of the rudder in the direction appropriate to the phase of the amplifier unit input.

84. A self-balancing or feed-back circuit is introduced from the rudder dual differential servo to the servo amplifier. Movement of the dual differential servo results in a feed-back signal proportional to such movement, appearing at a summing point preceding the amplifier input. When this signal nulls the input signal to the servo amplifier, the servo circuit is balanced and further movement of the rudder does not take place. Upon the input signal to the amplifier being cancelled, the feed-back signal operates the amplifier causing the rudder to be returned to its original position.

85. The rudder dual differential servo valve is described in the Flying Controls Service Data Ref. No. 15.

86. Signals are supplied by the sensing devices in the normal mode system in respect of yaw rate, transverse acceleration, and aileron position differential by, respectively, a yaw rate gyro, a transverse accelerometer, and a transducer. A signal which is the product of pitch rate and aileron position is also provided. All signals are compensated for airspeed by air data transducer components.

87. The yaw rate and aileron position signals are supervised by an integrator unit whose action is similar to that of the pitch axis sensing circuit integrator in that it has no effect

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on signels of short duration but nullifies steedy signals. The integrator also supervisea trens-verse accelerometer aignels when the lending geer is selected down.

Yaw Rete

88. The yew rate aignel produced by the yaw rate gyro is of e magnitude end phese eppropriate to the rete and direction of yawing motion. Since the gyro signel is proportional to rete of yaw rether than to displacement of the aircreft, comperetively quick correotive ection by the rudder can be achieved before the displecement becomes significent. If, in streight end level flight or during turning movements, the yaw rete signel is the result of trensient yawing motion, it is epplied through the verious summing points to the servo amplifier to effect e corrective movement of the rudder. As the aircreft returns to its original attitude, yew rete signala of the opposite phese ere produced which ceuse the deflection of the rudder in the opposite direct-ion to prevent overshoot. Steedy stete yew rate signale will cause an initiel deflection of the rudder but, due to the ection of the integretor, the rudder will be returned to its original pos-ition by the feed-beck signal.

Aileron Position

89. An eileron position signal is produced when the ailerons are moved to commence a turn or to meintein stebility. The position of the eilerons is translated by a trensducer into en electrical signal, the megnitude end phese of which is dependent on the degree end direction of eileron movement. Note thet, es the trensducer signal is the product of eileron poeition differential, the simulteneous up deflection of the eilerons et high eltitude will not result in e signel from the trensducer. See elso pere 51. The trensducer signal is applied through the verious summing points to the servo amplifier to effect the deflection of the rudder in the direction eppropriate to turn the eircreft end overcome edverse yewing moment resulting from aileron movement.

90. If the eileron position trensducer signal is the result of e commended turning menoeuvre or of en epplied eileron trim, the signal will be, in effect, e steedy state signel. Therefore, as with e steedy stete yaw rete signal, the integrator ection will ceuse the rudder to be re-turned to its original position after the initiel deflection or short term co-ordinetion. Trens-ducer signals resulting from the positioning of the eilerons by the sensing circuit will contin-ually position the rudder to provide co-ordinetion es required by the corrective movements of the ailerons. As the signels originated by the sensing circuit ere of reletively short duretion, they will not be nulled due to the operating time lag of the integretor.

Trensverse Acceleration

91. Slip or skid in eny flight ettitude results in e aignal origineted by the tranaverse eccelerometer being supplied to the servo amplifier to produce e corrective movement of the rudder. As the sideslip motion is eliminated by the epplied correction, the output of the trans-verse eccelerometer correspondingly decreeses so permitting the servo feed-beck signel to de-crease the deflection of the rudder.

92. When the landing geer is selected down, certein circuit chenges ere effected to by-pess the major portion of the trensverse eccelerometer signal to the summing point of the yew rete end eileron position signals. This action subjects the accelerometer signal to supervision by the integrator which nullifies the signal. By this meens, the pilot can introduce sideslip without opposition from the yaw axis chennel as the eccelerometer signels resulting from inten-tionel sideslip will be nullified by the integrator. The portion of the eccelerometer signal which is not by-pessed tends to meintain stebility in the axis.

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Aileron Position - Pitch Rate

93. The simultaneous command of a large rate of roll and degree of pitch would introduce an adverse yawing moment. The signal which is the product of aileron position and pitch rate is utilized in the yaw axis to counteract this condition. The magnitude of this signal is directly proportional to the aileron position commanded and degree of pitch. The signal supplements the short term rudder co-ordination signal, so increasing the deflection of the ruddar in relation to the attitudes commanded. As this signal is not supervised by the integrator, rudder deflection is applied until the command signals are cancelled.

94. With the exception of the aileron position and pitch rate signal the operation of the emergency mode system is identical with that of the normal mode system. The change-over from the normal mode to the emergency mode is effected by the operation of a rudder monitor which initiates the operation of certain electrical circuits of the rudder dual differential servo and results in the illumination of the roll and/or pitch axis disangage indicator light on the master warning system panel. The operation of the emergency yaw damper system is indicated by the illumination of the yaw emergency damper operative indicator, also located on the master warning system panel. The operation of the rudder dual differential servo is described in Service Data Ref. No. 35.

95. Note that when the rudder monitor is operated, the pitch axis and roll axis damper circuits are also disengaged. See the Pitch Axis and the Roll Axis Disengage Circuits.

Rudder Monitor

96. The rudder monitor circuit includes a sideslip switch i.e. the beta vane in the nose boom and two transverse accelerometers which are located 13 feet and 40 feet, respectively, forward of the aircraft's centre of gravity. The sideslip switch is set to open and interrupt the normal mode system supply if the sideslip angle exceeds ten degrees. This function is primarily for low airspeeds in which condition a small acceleration may correspond to a large angle of sideslip.

97. The action of the accelerometers is such that one detects direction of sideslip and other yawing acceleration. If yawing acceleration is sensed which tends to reduce sideslip the change-over circuit will operate at a transverse acceleration value of approximately $\pm$ 0.6 'g' at the centre of gravity. Conversely, if the yawing acceleration is such that it tends to increase sideslip the changeover circuit will operate at the relatively lower transverse acceleration values of $\pm$ 0.2 'g'. This configuration is necessary due to the fact that in co-ordinated manoeuvres relatively large values of transverse and yawing accelerations are required for which the monitor must make provision.

Rudder Feel, Trim and Hinge Moment Limitation

98. A trim circuit is provided to permit the rudder to be trimmed to compensate for steady state yawing motion resulting from asymmetric flight or other causes. The circuit is controlled by a trim switch located in the front cockpit and consists of an actuator fitted as an integral component of the rudder rear quadrant assembly. Operating the trim switch results in the actuator moving the linkage of the rudder hydraulic jack control valve. The movement of the rudder by the trim circuit does not effect the positioning of the rudder bar.

99. In addition to the trim actuator, the rudder rear quadrant assembly incorporates a rudder feel and hinge moment limitation system. This system functions automatically and its action is to decrease the rudder movement for a given force on the rudder bar in proportion to increasing airspeed. This is done to counteract the increased sensitivity of the rudder at high airspeeds.

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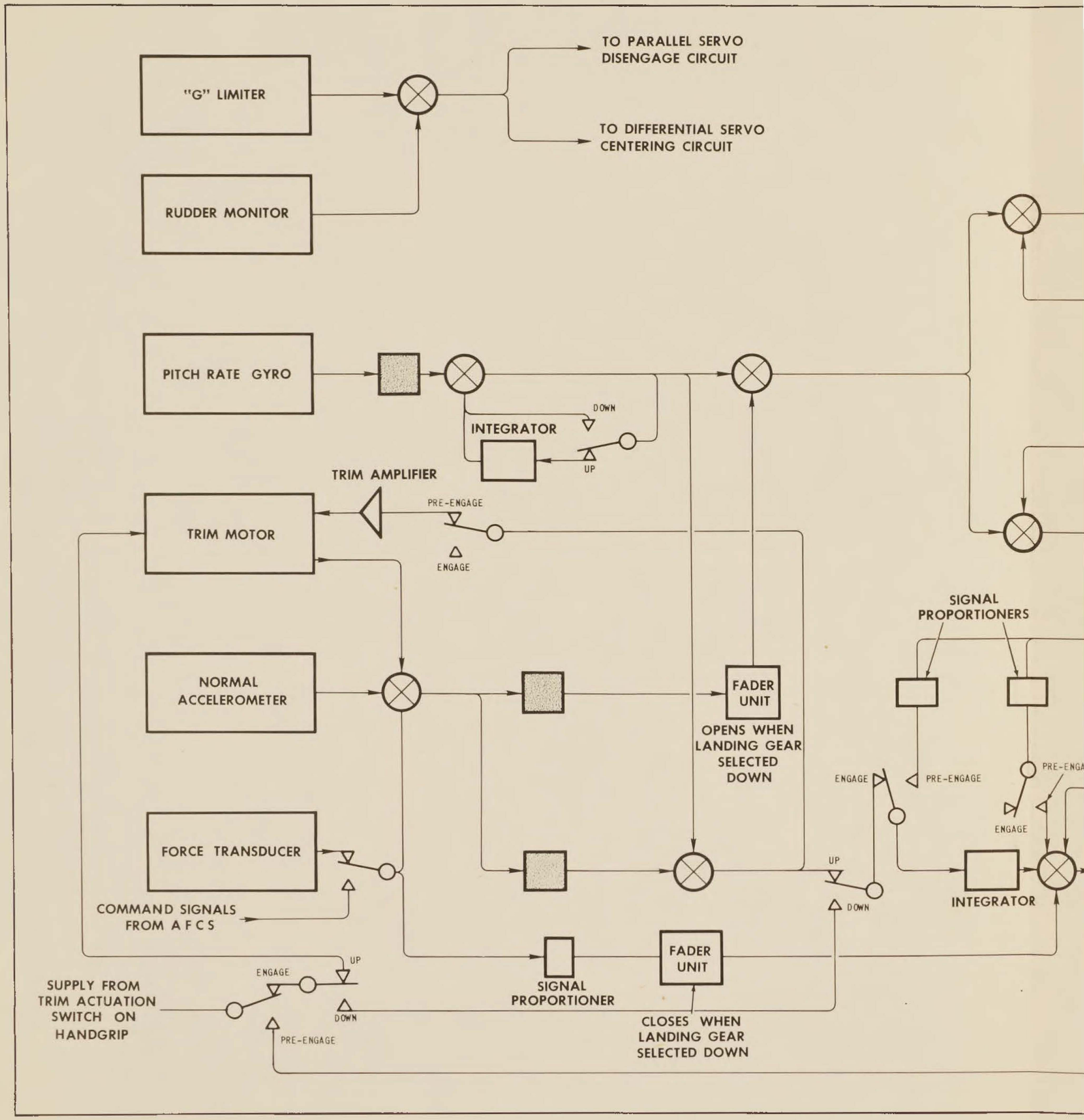
100. The operation of the trim circuit and the hinge moment limitation system are described fully in Service Data Ref. No. 15.


"G" LIMITER
RUDDER MONITOR
TO PARALLEL SERVO DISENGAGE CIRCUIT
TO DIFFERENTIAL SERVO CENTERING CIRCUIT
PITCH RATE GYRO
DOWN
INTEGRATOR
UP
TRIM AMPLIFIER
TRIM MOTOR
PRE-ENGAGE
ENGAGE
NORMAL ACCELEROMETER
FADER UNIT
OPENS WHEN LANDING GEAR SELECTED DOWN
SIGNAL PROPORTIONERS
ENGAGE
PRE-ENGAGE
PRE-ENGA
ENGAGE
FORCE TRANSDUCER
COMMAND SIGNALS FROM A F C S
UP
DOWN
INTEGRATOR
SUPPLY FROM TRIM ACTUATION SWITCH ON HANDGRIP
ENGAGE
UP
DOWN
PRE-ENGAGE
SIGNAL PROPORTIONER
FADER UNIT
CLOSES WHEN LANDING GEAR SELECTED DOWN

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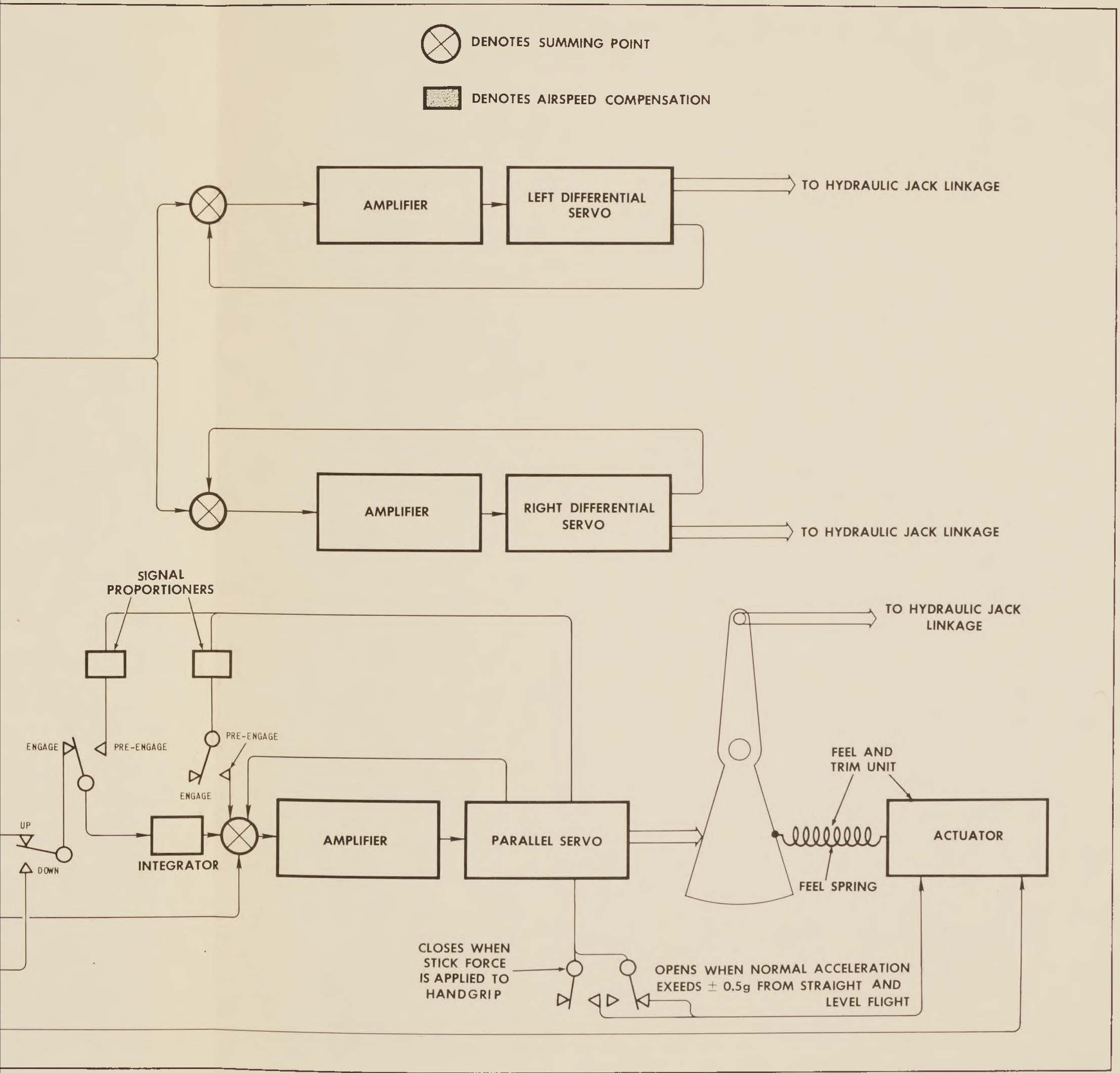

FIG. 1 PITCH AXIS BLOCK DIAGRAM

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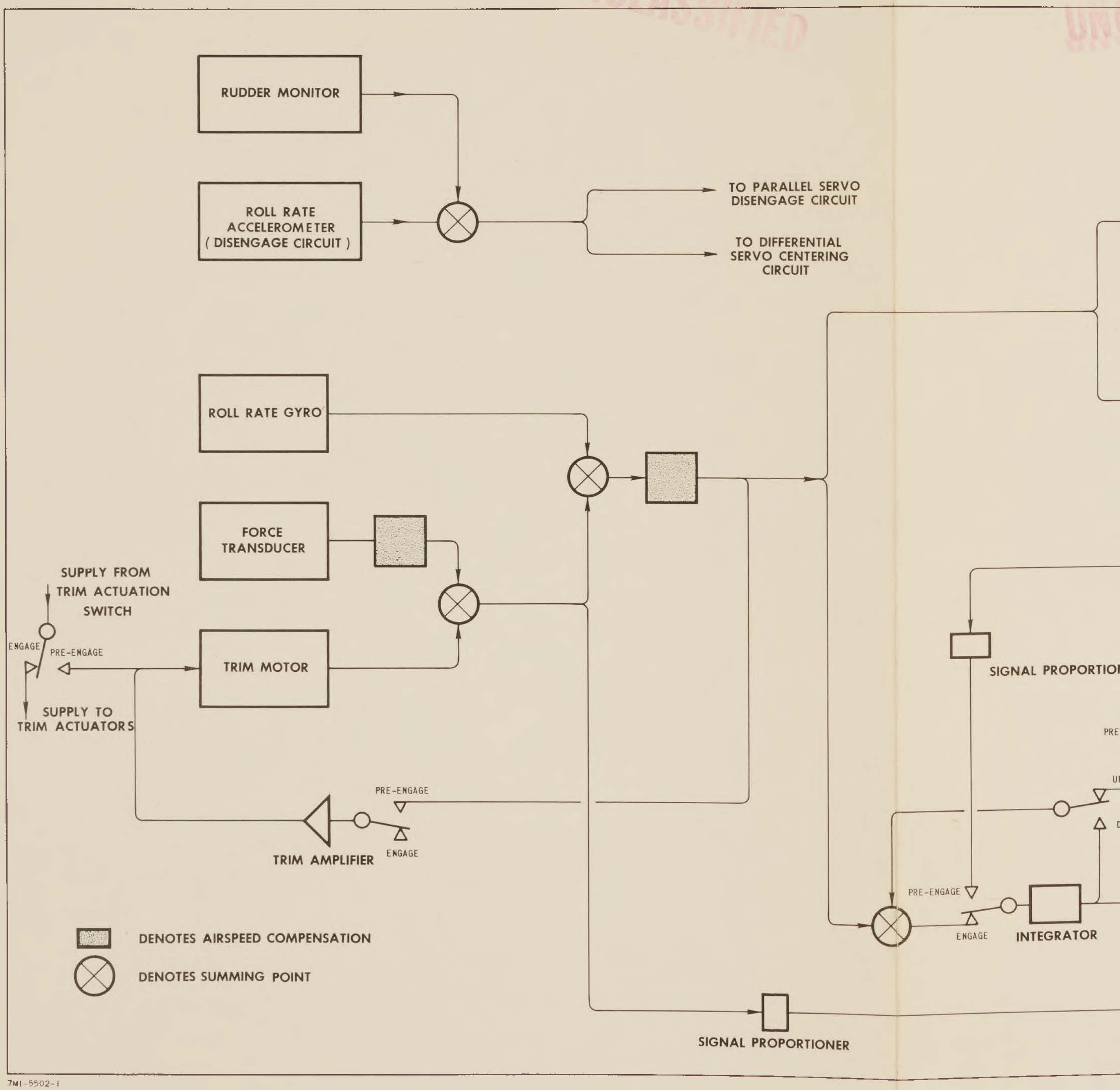

FIG. 2 ROLL AXIS BLOCK DIAGRAM

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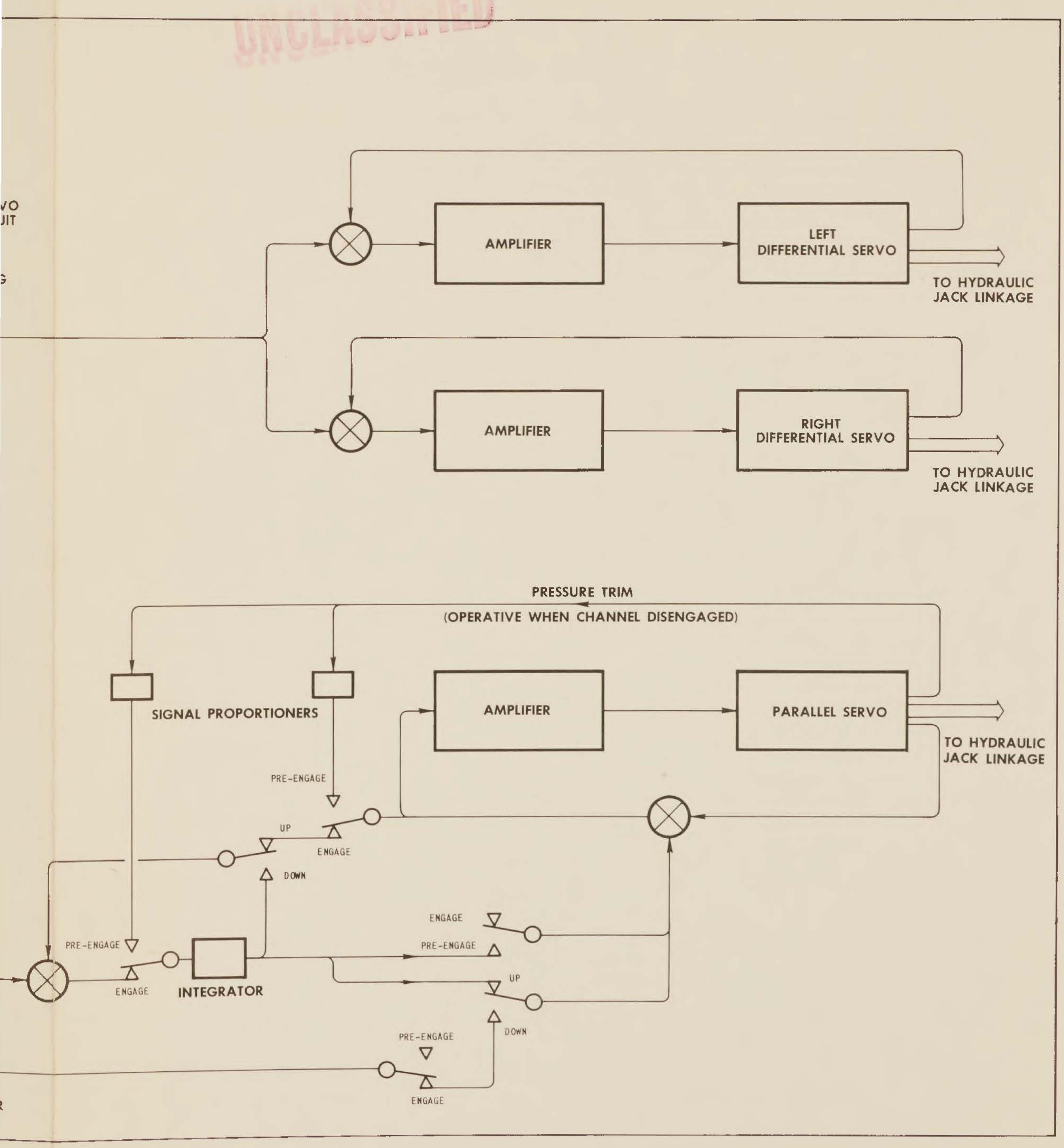

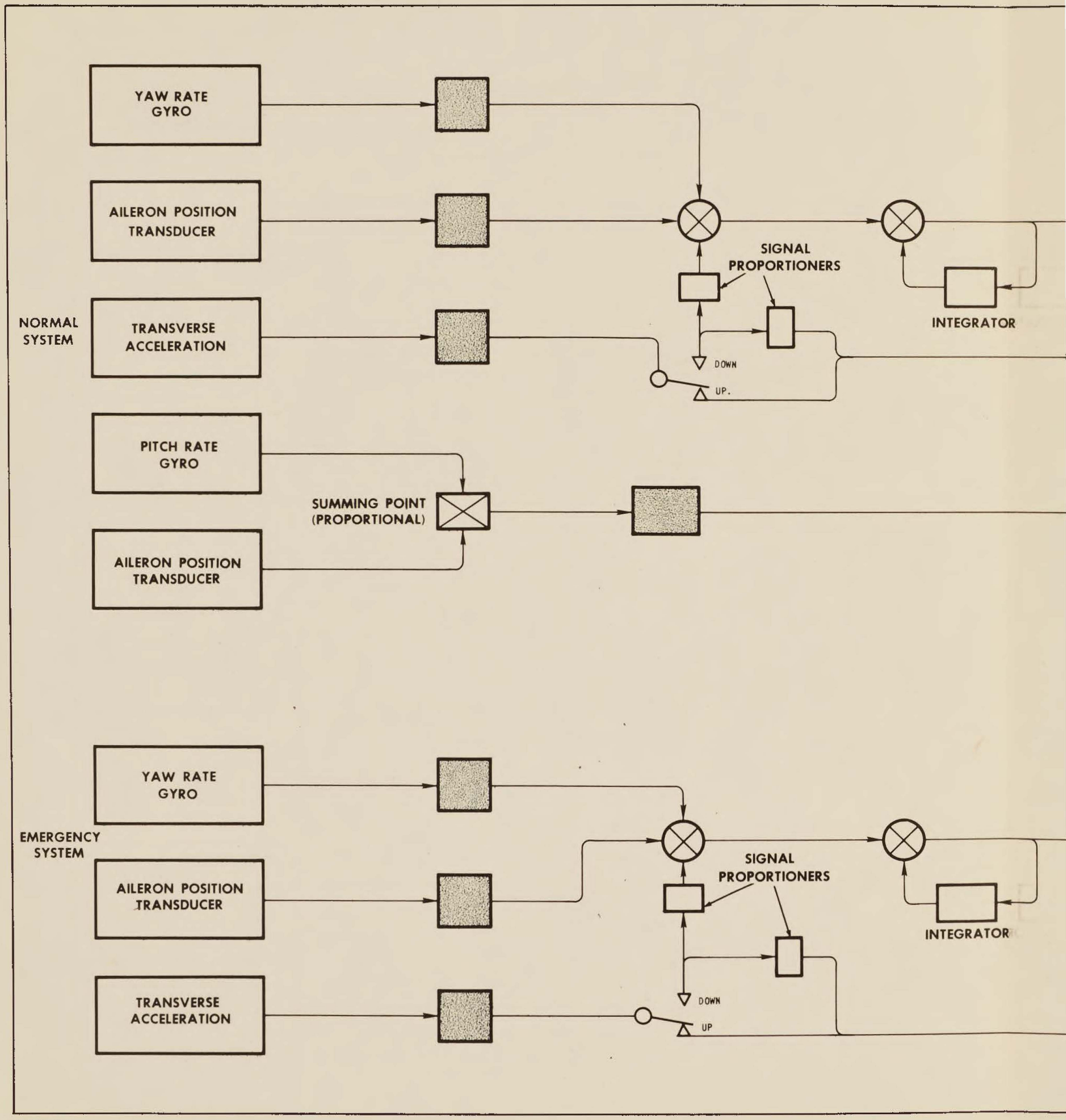
YAW RATE GYRO
AILERON POSITION TRANSDUCER
NORMAL SYSTEM
TRANSVERSE ACCELERATION
SIGNAL PROPORTIONERS
INTEGRATOR
DOWN
UP.
PITCH RATE GYRO
SUMMING POINT (PROPORTIONAL)
AILERON POSITION TRANSDUCER
YAW RATE GYRO
EMERGENCY SYSTEM
AILERON POSITION TRANSDUCER
SIGNAL PROPORTIONERS
INTEGRATOR
TRANSVERSE ACCELERATION
DOWN
UP

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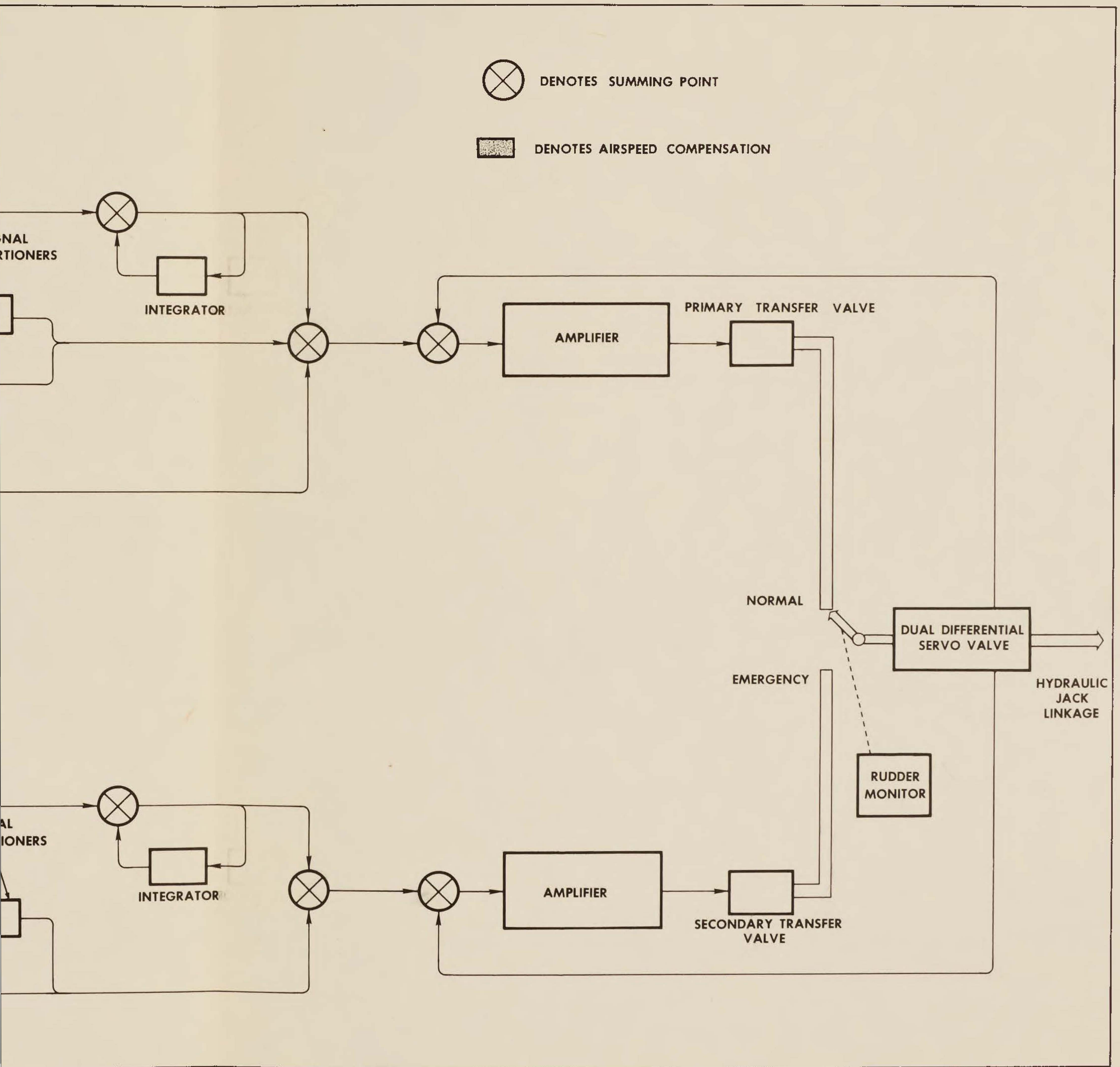

FIG. 3 YAW AXIS BLOCK DIAGRAM

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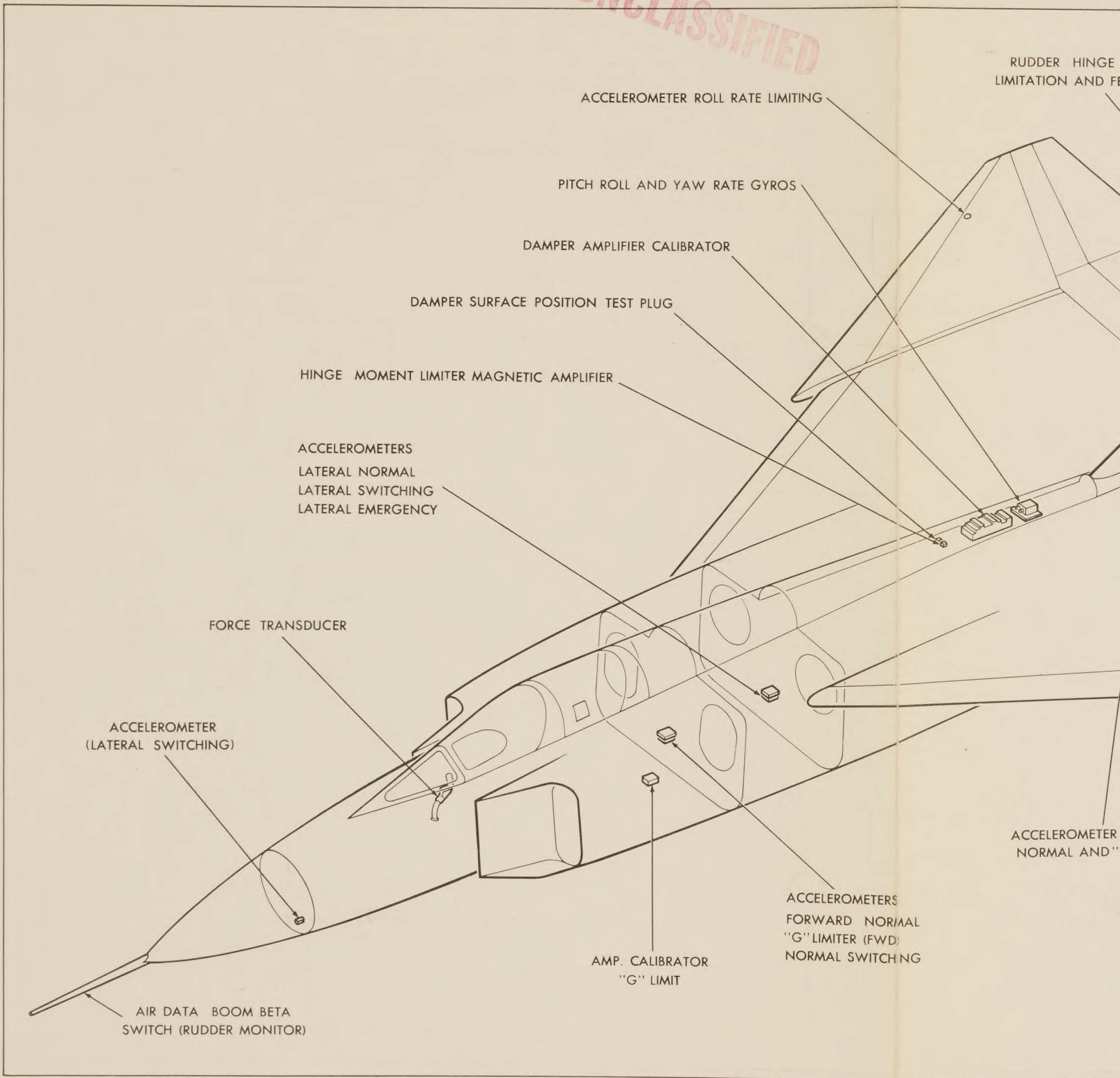

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FIG. 4 LOCATION OF DAMPER SYSTEM COMPONENTS

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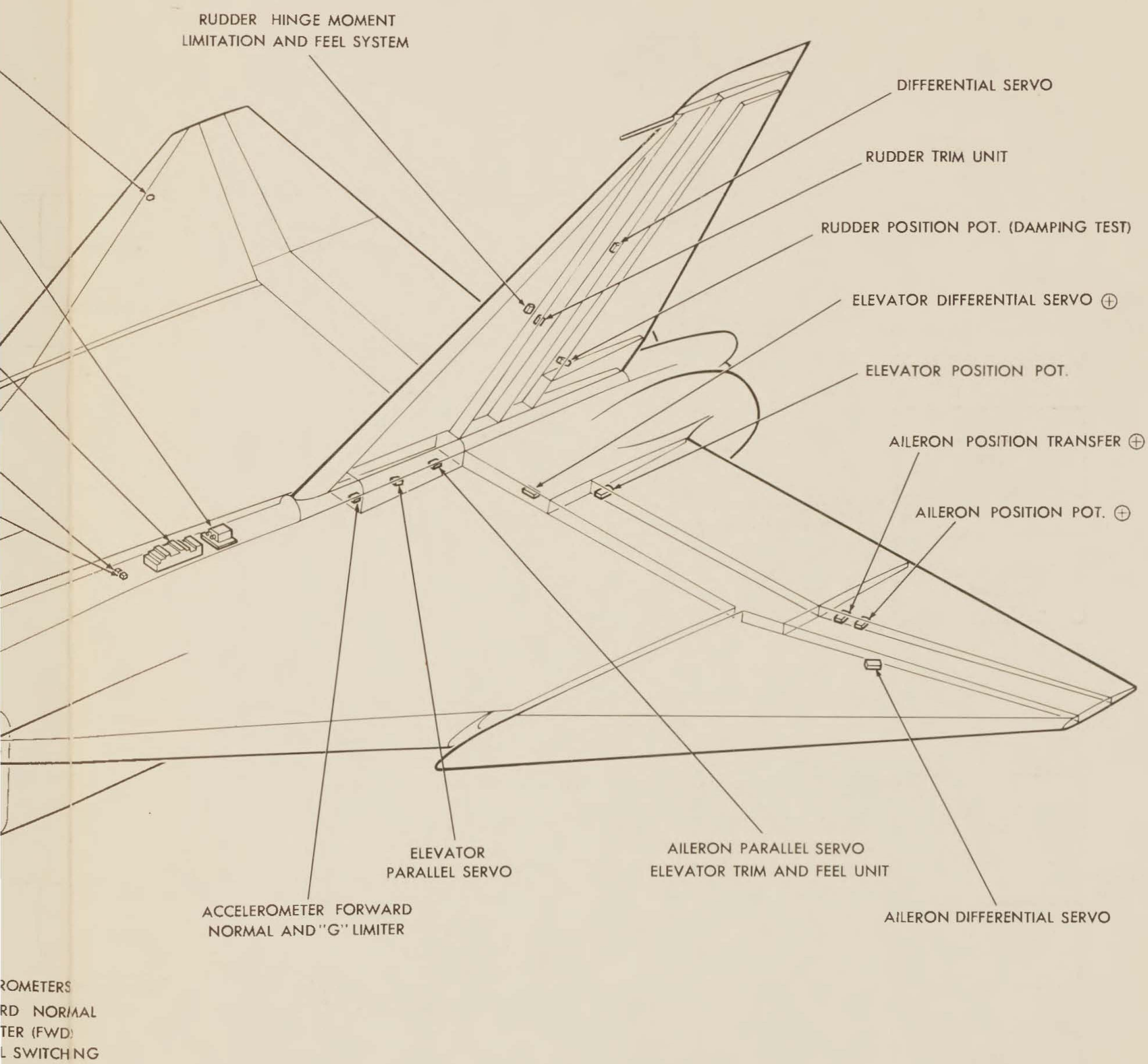

⊕ INDICATES EQUIPMENT LOCATED IN A
SIMILAR POSITION ON OPPOSITE WING