FLIGHT CONTROLS SYSTEM

DESCRIPTION

Primary flight control of the aircraft is provided by aileron, elevator and rudder control surfaces. The elevator and rudder control surfaces are mechanically operated. The aileron control surfaces are hydraulically boosted with mechanical inputs. Secondary flight control systems comprises wing trailing edge flaps, leading edge slats and air brakes (two inboard and two outboard). The flight controls travel is outlined in the following table:

FLIGHT CONTROLS TRAVEL

Surface	Travel	Direction	Notes
Aileron	-15° +15°	UP DOWN	Surface trailing edge
Aileron Trim	-4° +4°	UP DOWN	Surface trailing edge
Rudder	22° 22°	Left Right	
Rudder Trim/Gear Tab	11° 30’ 11° 30’	Left Right	
Elevator	22° 30’ 12°	Nose up Nose down	Trailing edge up Trailing edge down
Elevator Tab	3° 18°	Nose up Nose down	Trailing edge up Trailing edge down
Horizontal Stabilizer Trim	12° 1°	Nose up Nose down	Trailing edge up Trailing edge down
Column	11.6° 8°	Aft Forward	
Control Wheel	78° 78°	Left Right	
Pedal	3” 3”	Left Forward Right Forward	

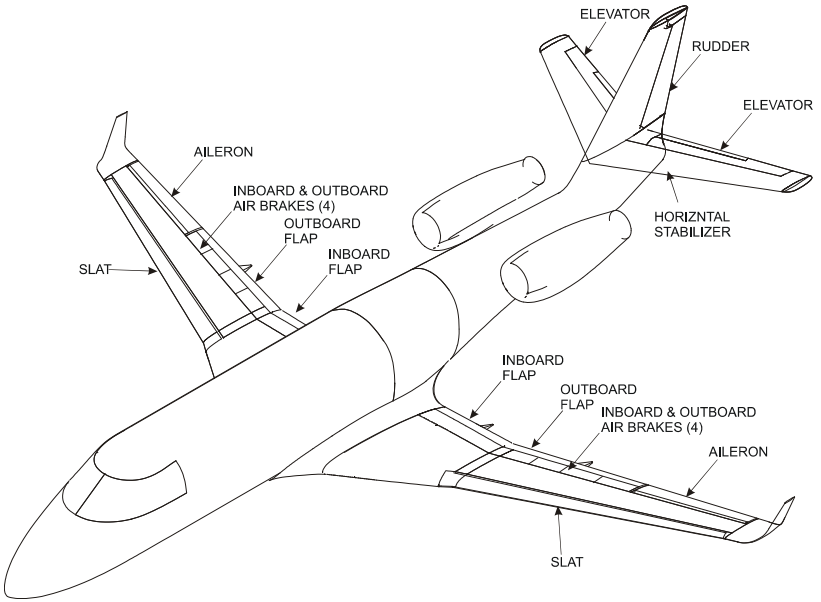

Figure 7-27-1. Flight Controls

LATERAL CONTROL

The left and right aileron control surfaces are activated mechanically and hydraulically boosted by independent dual hydraulic servoactuators, one located in each outer wing. One side of each dual actuator is powered from the main hydraulic system and the other side from the auxiliary hydraulic system.

One hydraulic system only is sufficient for safe maneuvering of the aircraft. Even with total loss of hydraulic power, it is possible to fly the aircraft manually. During climb, cruise, and descent, with landing gear retracted, the auxiliary hydraulic system does not operate unless there is a failure in the main system, and the actuators are powered only by the main system. Both main and auxiliary systems provide power to their respective sides of each actuator when the landing gear is extended. Both servoactuators receive mechanical inputs from the aileron control wheels in the cockpit through the control column-cables. Quadrants below cockpit floor transfer movement to left and right push-pull rod assemblies.

The aileron control rods run to the left and right torque tube assemblies at fuselage frame 27. The left and right ailerons disconnect rod, artificial feel unit, trim actuator and autopilot trim servo are located in the wing carry through structure (CTS). Control wheels inputs are mechanically transferred to move the servo actuators which are attached to the ailerons. Hydraulic pressure powers the servoactuators to move the aileron control surfaces to the desired position.

If the control linkage is disconnected, the affected actuator is centered by a spring. Each cylinder has an integral bypass valve which allows direct interflow between both sides of the piston when hydraulic power is not available, to prevent hydraulic lock of the servo actuator.
An aileron trim actuator is incorporated within the aileron primary control system. It comprises an electro-mechanical linear actuator with a reversible motor.

(Continued)

Artificial feel unit (AFU) provides control input feedback, using physical tension and compression of the springs in the unit. Aerodynamic reaction forces at the control wheel are simulated by the AFU. The AFU increases the reaction on control wheel in proportion to the aileron deflection. Aileron trim actuator is connected to the AFU. It relieves control loads by shifting the neutral position of ailerons. This actuator also enables control of the aileron actuators at limited authority (about 1/3 stroke).

The aileron actuators are connected to a compensator to provide sufficient damping in order to prevent flutter of an unbalanced aileron surface during total hydraulic failure.

The aileron controls incorporates an autopilot actuator with disengaging clutch to prevent the system from jamming during actuator failure.

During normal operation the roll control forces do not exceed 180 inch-pounds including friction. The total breakout force from neutral position does not exceed 32 inch-pounds.

If aileron control is jammed, the connection between left and right aileron can be broken by pilot and copilot simultaneously rotate the control wheel inboard, applying sufficient pressure on the ailerons mechanical system to break interconnecting rod.

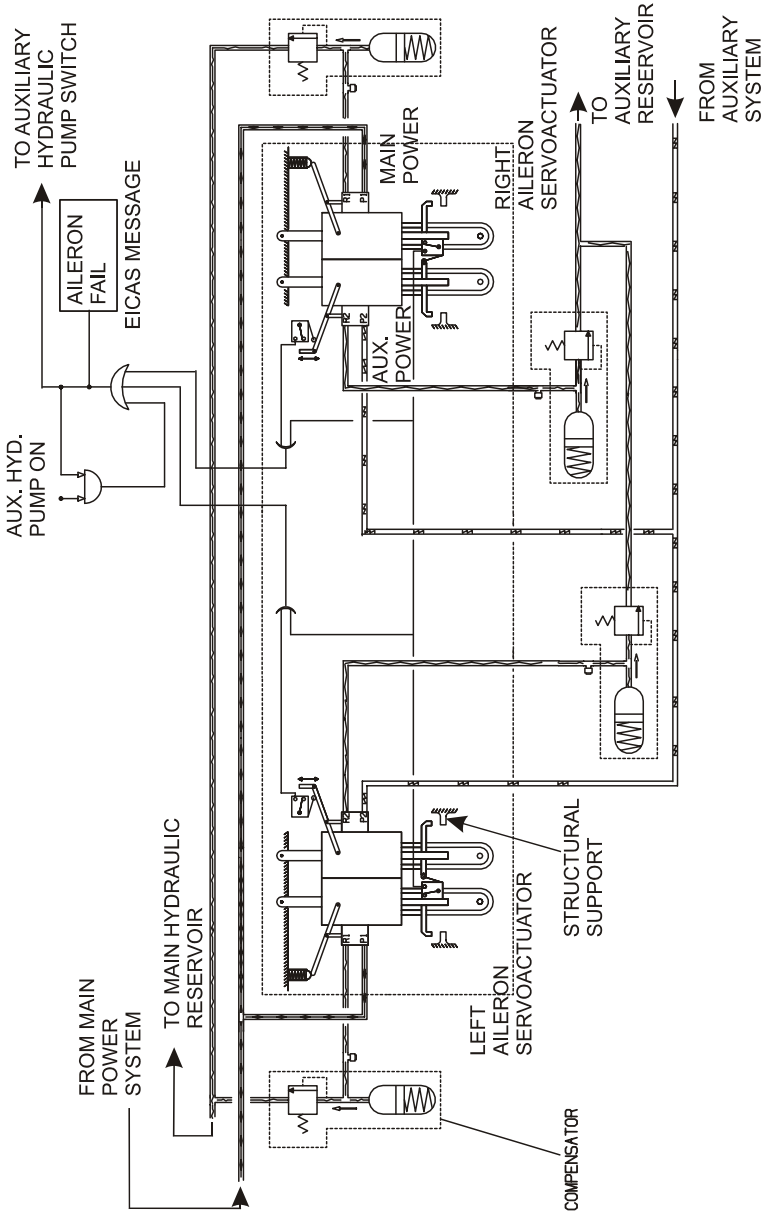

Figure 7-27-2. Aileron System - Schematic

DIRECTIONAL CONTROL

Rudder control is mechanical, operated by either pilot through rudder pedals. Control rods, bellcrank levers, linkages and torque shafts convey mechanical inputs from the pilots rudder pedals to the torque tube attached to the rudder, to position the control surface.

Fore and aft motion of the pilot and copilot rudder pedals turn the torque tubes connected to a common bellcrank from which the motion is transmitted to push-pull rods under the cabin floor on the aircraft left side, which connect to bellcranks forward of the aft pressure bulkhead. The rudder control surface incorporates a single tab which operates as both servo tab and trim tab. The tab aerodynamically boosts rudder inputs in flight, to reduce control forces. Two electrical actuators drive the tab for rudder trim.

The rudder controls incorporates an autopilot actuator with disengaging clutch to prevent the system from jamming during actuator failure.

An independent rudder pedal adjustment mechanism is provided at each pedal.

A gust lock is provided, engaged and disengaged through the cockpit gust lock lever. It protects the rudder and elevator against potentially damaging gust loads on ground. The gust lock, when engaged, also prevents power lever movement beyond idle.

LONGITUDINAL CONTROL

Pitch control is mechanical, operated by either pilot through fore and aft movement of the mechanically linked cockpit control columns. Control rods, bellcrank levers, linkages and torque shafts convey mechanical inputs from the pilots control columns to the conventional, interconnected, twin elevators to position the surfaces. Each elevator is provided with a non-linear gear tab to boost elevator inputs in flight and to reduce control forces.

Longitudinal trim is achieved by movable horizontal stabilizer, operated by two independent electrical trim systems for redundancy. Trim indication is in the EICAS primary page. The actuator incorporates three electric motors.

If elevator is jammed or disconnected, all three motors operate in unison and the horizontal stabilizer serves in place of elevator for longitudinal control. The elevator incorporates an autopilot actuator with disengaging clutch to prevent the longitudinal system from jamming during actuator failure. A gust lock is provided, engaged and disengaged through the cockpit gust lock lever. It protects the rudder and elevator against potentially damaging gust loads on ground. The gust lock, when engaged, also prevents power lever movement beyond idle.

TRIM SYSTEMS

Horizontal Stabilizer Trim

The electromechanically driven, variable incidence horizontal stabilizer provides longitudinal (pitch) trim. The stabilizer travel is +1° to -12°, which covers the entire flight and cg envelope trim requirements. There are two electrically independent drive systems, with separate switches, wiring and motors, for redundancy (No. 1 or Normal system and No.2 or Override system). If both these systems fail, or for high rate operation to regain pitch control in the case of an emergency caused by jammed or disconnected elevator, the normal and override system motors operate together with a third motor, all controlled through a separate cockpit switch. All three motors are incorporated into a single drive unit that mechanically positions the stabilizer leading edge. Readout of trim position is on the EFIS display.

Normal Operation

Pitch trim switches, on the top of the outboard grips of the pilot and copilot control wheels, control normal operation. Each is a three position switch spring loaded to the center (off) position. The forward momentary position (NOSE DN) provides nose down trim, and the aft momentary position (NOSE UP) provides nose up trim. The autopilot also uses the normal system for pitch trim. The Mach trim function operates when the autopilot is disengaged in the flight regime in which trim adjustment for Mach effects is needed (0.79 M_i and above) as received via air data computer Mach data. The trim actuator incorporates limit switches that restrict stabilizer travel when operation is through the normal system only. A pitch trim tone sounds in the cockpit when the normal system operates for more than one second.

Override Operation

If the normal system fails to operate, the pilot can regain pitch trim capability by pressing the PITCH TRIM REL switch located on the right (inboard) grip of the pilot's control wheel. This de-energizes the normal (primary) pitch trim system and energizes the override system. The light in TRIM OVRRD pushbutton comes on.

With the override pitch trim system energized, control of pitch trim is through the pedestal mounted HORIZ TRIM three position switch. The HORIZ TRIM toggle switch is spring loaded to the center (off) position. Holding the switch to the momentary NOSE DN (forward) position provides nose down trim and holding it in the momentary NOSE UP (aft) position provides nose up trim through operation of the override (secondary) electric trim motor. The override trim motor does not incorporate limit switches. Therefore, during override operation the pilot must monitor trim position indication to ensure that stabilizer travel remains within safe limits. To return power and control to the normal (primary) pitch trim system the pilot presses the lighted TRIM OVRRD pushbutton and observes the light go out. Power is then removed from the override system and restored to the normal system.

Emergency Operation

The emergency pitch trim system provides a means to regain pitch control in the event of the jamming or disconnection of the elevators. It may also be used to restore pitch trim functionality if both the normal (primary) and override (secondary) pitch trim systems fail. The emergency trim system is energized by pressing the guarded, lighted pushbutton EMERG ARM switch on the pedestal. The light in the switch comes on. Control of pitch (or pitch trim) is then through the EMERGENCY TRIM switch located on the left (outboard) grip of the pilot control wheel. This is a three position switch, spring loaded to the center (off) position. Momentary movement of the switch forward provides nose down trim and holding it aft provides nose up trim. The system operates three electric pitch trim motors simultaneously (normal, override, and a third (emergency) motors). Trim operates at three times the normal rate without limit switch protection. The system should be used with caution and trim position monitored. Pressing EMERG ARM pushbutton again de-energizes the emergency system and the EMERG ARM light goes out.

Rudder Trim

Rudder trim is accomplished by moving a trim tab on the rudder. This tab is operated by two mechanically interconnected electrical actuators, each protected by separate circuit breaker. Both actuators are installed in the rudder structure and are attached (at their forward end) to the vertical stabilizer.

The geometry of this attachment causes the tab to deflect one degree in the opposite direction for every three degrees of rudder travel, which produces aerodynamic boost to lessen control forces in flight.

The actuators incorporate mechanical non-jamming stops. The upper actuator houses a linear potentiometer for the tab position transmitter.

Aileron Trim

Aerodynamic forces are simulated at the control wheels by the artificial feel unit (AFU) consisting of a spring box attached to the aileron control linkage. The AFU causes an increase the force to increase the wheel displacement in roll proportional to the aileron deflection, thus providing artificial feel to the pilots. The electrically powered aileron trim actuator is connected to the AFU. Operation of the aileron trim actuator causes the neutral point of the AFU to be displaced favoring left or right wing down as selected by the pilot by shifting the neutral position of aileron. The AFU has maximum authority of about 1/3 aileron displacement. The aileron trim function is controlled from three position AILERON switch on the pedestal (spring loaded to the center (off) position). Momentary displacement of the AILERON switch to the LW DN or RW DN position causes operation of the aileron trim actuator to reset neutral feel in the left wing down or right wing down direction respectively. Trim indication is displayed on the EICAS primary page.

Trim Controls

Pitch Trim switches (2) - Located on each outboard grip of pilot and copilot control wheels. The switches have three positions:

Center - Stops horizontal stabilizer trim operation.
NOSE DN - Momentary position to trim nose down. Spring loaded to center.
NOSE UP - Momentary position to trim nose up. Spring loaded to center.
Pilot pitch trim switch has priority over copilot switch.

PITCH TRIM REL. Button - Located on pilot control wheel inboard grip. Pressing the button deactivates normal system and arms OVRD system; OVRRD button light comes on.

HORIZ TRIM ovrerride switch - Controls the override trim system in the same manner the normal pitch trim switches control the normal system.

CAUTION

WHEN USING OVERRIDE SYSTEM, OBSERVE TRIM POSITION INDICATOR. ELECTRICAL LIMIT STOPS ARE NOT PROVIDED.

TRIM OVRRD button - When pressed, the override system is de-energized and normal system is armed. It lights up when PITCH TRIM REL. button is pressed.

(Continued)

EMERG ARM pushbutton - Pressing this pushbutton, on the pedestal, arms the emergency pitch control mode (all three trim motors operate in parallel) for fast horizontal stabilizer movement enabling pitch control with a jammed or disconnected elevator.

Emergency Trim switch - Located on the left grip of the pilot control wheel, left of the normal trim switch. The switch is activated by pressing the EMERG ARM pushbutton switch on the pedestal.

AILERON trim switch - Has three position as follows:

Center - Stops aileron trim operation.
RW DN - Momentary position. Moves control wheel to right (right roll).
LW DN - Momentary position. Moves control wheel to left (left roll).

RUDDER Trim Switch - Has three positions as follows:

Center - Stops rudder trim operation.
NOSE R - Momentary position. Trims rudder to right.
NOSE L - Momentary position. Trims rudder to left.

Warning Messages

CONFIG TRIM 🔈 - Aircraft on ground, both power levers beyond 70% N_1 and horizontal stabilizer trim out of green band for the selected flaps setting

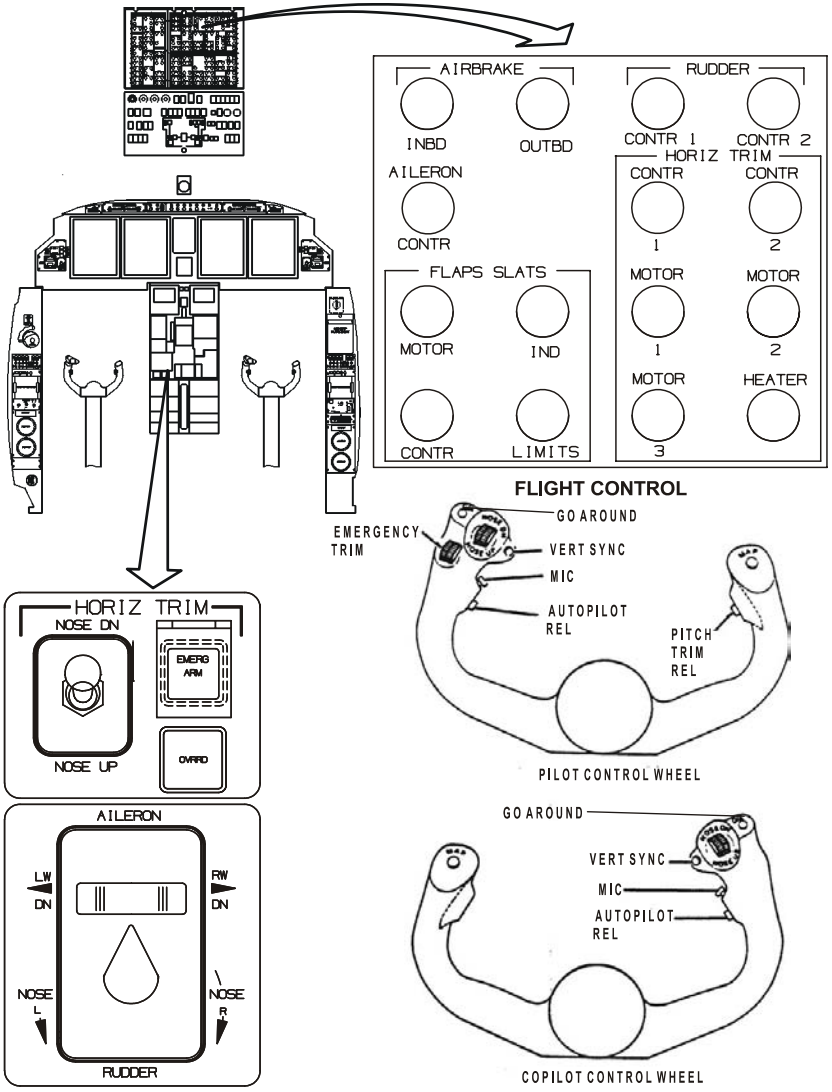

Figure 7-27-3. Trim Controls

FLAPS / SLATS

Each wing is equipped with two flap panels and one slat surface, driven by independent flap and slat drive systems.
Flaps and slats systems are controlled by a common flap / slat electronic control unit (FSECU).
Flap and slat surfaces ride on curved rails and are driven by irreversible linear actuators. The linear actuators on both wings are mechanically interconnected by flexible shafts, driven by a central electrical power drive unit (PDU).
Flap and slat operation is consecutive. Slats extend first and retract last. The pilot can extend flaps without slats (override). Pressing SLATS BYPASS ARM pushbutton removes the flaps and slats primary drive motor protections. Therefore, it should be used only once, after slats system failure.
Slats extend automatically at high AOA to enhance flight characteristics as follows:

AOA/ Airspeed/ Mach No.	**Slats Action**
at or above 0.82 AOA at or below 250 KIAS at or below 0.55 M_i	extend to maximum

If 250 KIAS/0.55 M_i is exceeded with slats extended, V_{MO}/M_{MO} bell sounds.
After slats are automatically extended, retraction may be achieved only manually, by placing FLAPS/SLATS lever first in DN position, and then in UP position (provided AOA below 0.6).
Do not reverse flaps or slats position selection when surface is in motion. The system should come to a complete stop prior to reversing flaps or slats travel.

Extension times:
Slats (25°) 7.5 ± 1.5 sec
Flaps (40°) 27 ± 3.0 sec

Flaps / Slats Controls

SLATS/FLAPS control lever - Has five positions as follows:

UP - Flaps and slats are up (except when slats deploy automatically). DN - Slats are extended, flaps stay retracted.

12°; 20°; 40°; - Slats stay extended and flaps are extended, as required for the particular operation (take-off, approach or landing).

SLAT BYPASS ARM pushbutton - Used to stop and bypass slats operation if failure occurs to slats extension/retraction system. ARM light comes on.

CONTROLLER TEST switch (on pedestal side) - This switch is used to test the slats/flaps controller. The switch is spring loaded to center (off) position. Placing the switch in one of the four test positions, with FLAPS/SLATS lever in various positions, tests all of the system components (FLAPS/FLAPS position transmitters, drive disconnect switches, oleo switch connection, up/down limit switches, AOA signal input, V_{MO}/M_{MO} warning connection and bell and slats/flaps monitor power supply).

This switch is located on right pedestal side wall and it is intended only for maintenance checks.

Warning Messages

CONFIG FLAPS 🔊 - Aircraft on ground, both engines thrust beyond 70% N_1 and flaps position more than 22°

CONFIG SLATS 🔊 - Aircraft on ground, both engines thrust beyond 70% N_1 and slats position less than 23° with SLAT BYPASS pushbutton off

Caution Messages

AUTO SLATS EXTENDED - Slats automatic extension has been activated

AUTO SLATS FAIL - Failure in slats automatic extension system.

FLAPS UNBALANCE - Failure of flap system or asymmetry between left and right flaps is more than 3°

SLATS UNBALANCE - Failure of slat system or asymmetry between left and right slats is more than 3°

Advisory Messages

CONFIG SLATS BYPASS - Comes on due to take-off configuration setting of flaps - 20° and SLATS BYPASS selected

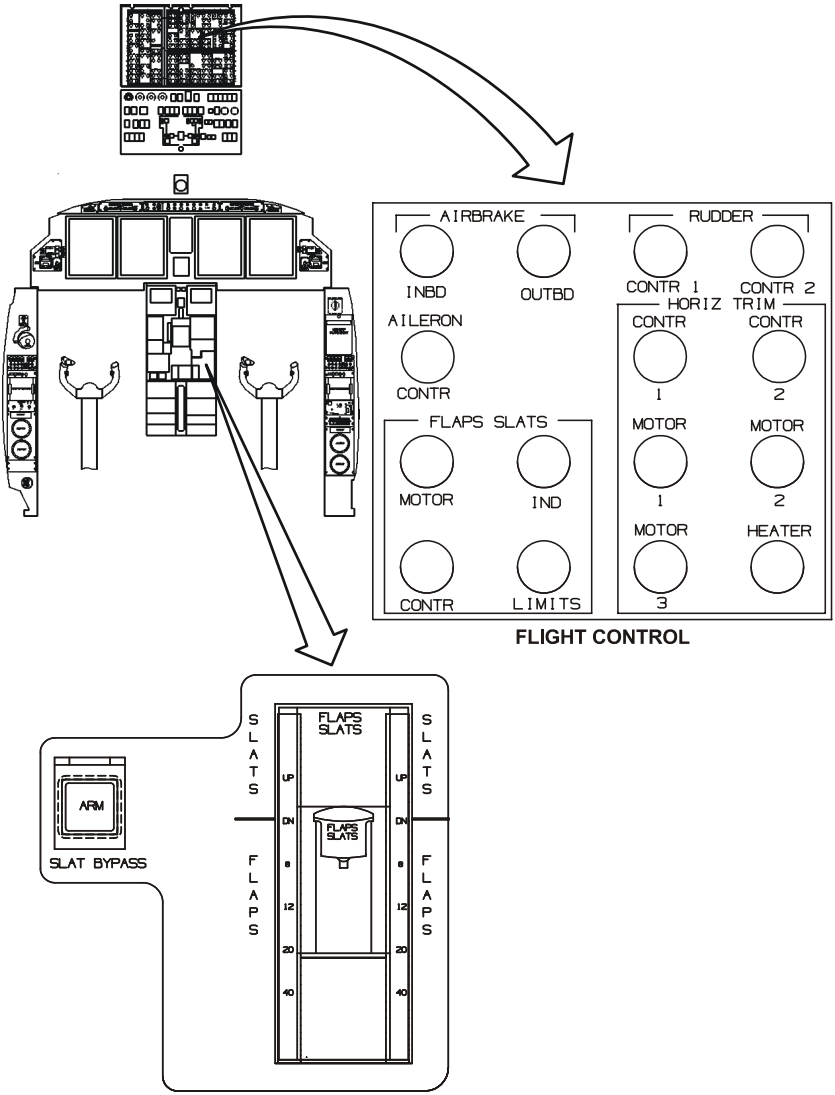

Figure 7-27-4. Flaps / Slats Controls

AIR BRAKES

There are four air brake panels on the upper surface of each wing. Each panel is attached at its leading edge. Individual hydraulic actuators are installed that rotate each panel, trailing edge upward into the airstream. On each wing, the inboard pair of panels act as either flight or ground air brakes, and the outboard panels act as ground air brakes only. The flight air brakes may be operated separately: outboard only, and both outboard and inboard. The surfaces are actuated by actuators fed from the main hydraulic system only. the actuators are mechanically locked in the stowed position.

Ground air brakes operate on the ground only and, when deployed, dump excess lift from the wing when aborting take-off or on landing. To prevent erratic extension and retraction of the ground air brakes during a bouncy landing, self holding relay bypasses the landing gear ground contact switch and holds the air brakes extended.
Flight air brakes may be extended in flight to increase drag at any airspeed and in any configuration.

Air Brakes Controls

GROUND A/B switch - Has three positions:

TAKEOFF - Take-off position. Deployment requires nose weight on wheels switches (WOW) (both in series) on ground, both power levers at less than 80%, airspeed more than 80 kias and one main WOW on ground.

OFF - Ground air brakes are retracted.

LAND - Landing position. Deployment requires both power levers less than 80% and one main WOW on ground.

(Continued)

FLIGHT A/B switch - Has three positions:

RETRACT - Flight air brakes are retracted.
OUTBD - Outboard flight air brakes are extended.
OUTBD & INBD - Both outboard and inboard flight air brakes are extended.

Warning Messages

CONFIG AIRBRAKE - Aircraft on ground, both engines thrust beyond 70% N_1 and air brakes are unlocked

Caution Messages

A/B T/O NOT ARMED - Ground air brakes not armed for take-off
GND BRK WOW MISCOMP - Ground-brakes-weight on wheels switches miscompare
FLT A/B OUTBD FAIL - Outboard flight air brakes position differs from switch command
FLT A/B INBD FAIL - Inboard flight air brakes position differs from switch command

Advisory Messages

FLT A/B OUTBD OUT - Flight (outboard)) airbrakes extended.
FLT A/B INBD OUT - Flight (inboard) airbrakes extended.

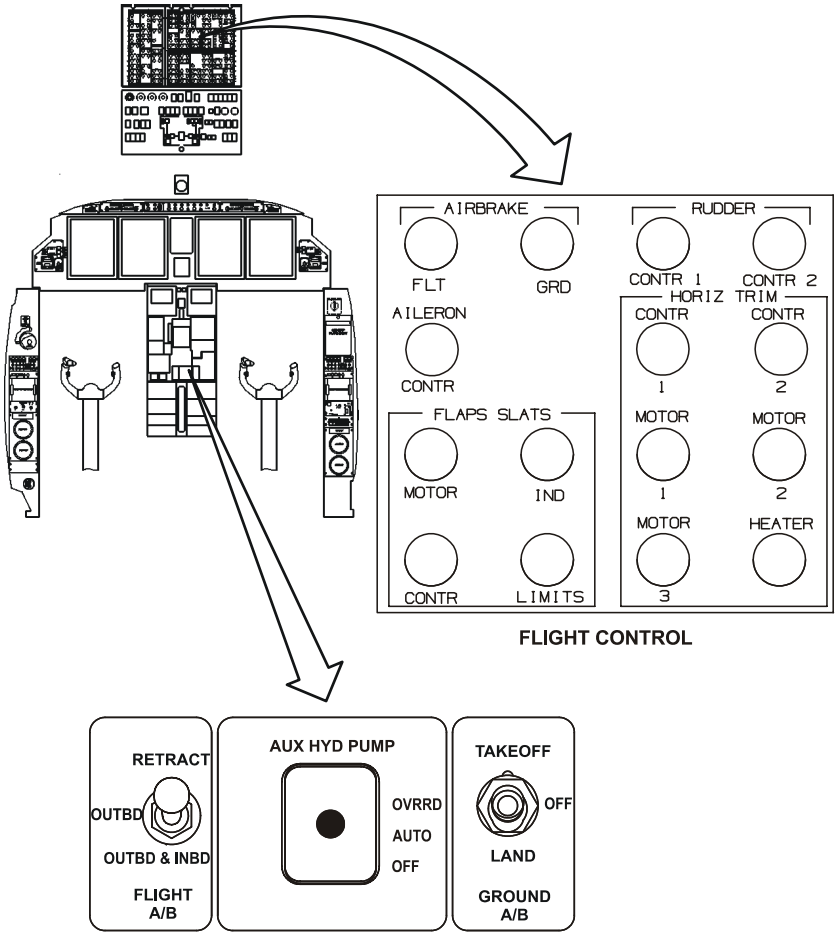

Figure 7-27-5. Air Brakes Controls