DOCUMENT NUMBER
GSM-G-CPL.009

DOCUMENT TITLE

AIRFRAME AND SYSTEMS
CHAPTER 5: FLIGHT CONTROLS

Version 1.0
September 2012

CONTENTS .... PAGE

INTRODUCTION

Flight controls are movable aerofoil structures fitted to the trailing edges of the wings and vertical and horizontal stabilizers to enable the pilot to control the aircraft in flight. Other secondary flight controls are movable aerofoil shapes located at other points on the aircraft. These assist the operation of the aircraft in particular phases of flight.

Depending on the type, size and speed of the aircraft the flight control actuation may be defined as;

- manual, which are reversible flight controls,
- partially powered, which are reversible flight controls, and
- fully powered, which are irreversible flight controls.

Reversible flight controls are <u>able to transmit</u> aerodynamic forces back to the cockpit controls. This enables the pilot to feel the load exerted when control inputs are made. When at rest on the ground, an aircraft with reversible flight controls requires locks to be inserted so that wind gusts cannot damage the components.

Irreversible flight controls are <u>not able to transmit</u> aerodynamic forces back to the cockpit controls. This therefore requires some form of artificial feel system to provide feedback to pilot inputs. When at rest on the ground, an aircraft with irreversible flight controls does not require locking of the flight controls.

There are numerous types of flight controls each with a specific name and function and they may be divided into two groups referred to as **PRIMARY** flight controls and **SECONDARY** flight controls.

Primary Flight Controls are obviously essential for flight and on almost all aircraft are the Ailerons, Elevators and Rudder, however, some aircraft may combine two of these controls together to create flight controls known as Elevons (elevator/aileron) and Ruddervator (rudder/elevator). Refer to Figure 5-1.

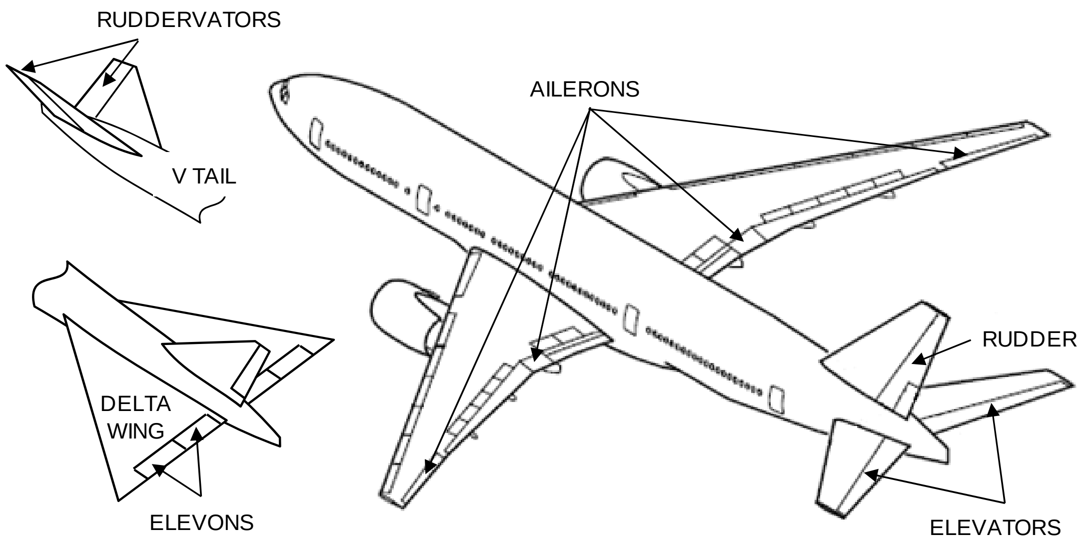


Figure 5-1 Primary Flight Controls

Additionally, some aircraft use some of the secondary flight controls such as spoilers to enhance or augment the operation of the primary controls.

Depending on the type, size and speed of the aircraft the primary flight controls will be either manual, partially powered or fully powered.

Secondary Flight controls are used to augment the flying operation of the aircraft at certain points such as take-off and landing and other phases of flight.

Depending on the type, size and speed of the aircraft the secondary flight controls may include Trailing Edge Flaps, Leading Edge Flaps, Leading Edge Slats, Spoilers, Speedbrakes, Yaw and Pitch Dampers, Horizontal Stabilisers, Trim Tabs and Servo Tabs. Refer to Figure 5-2.

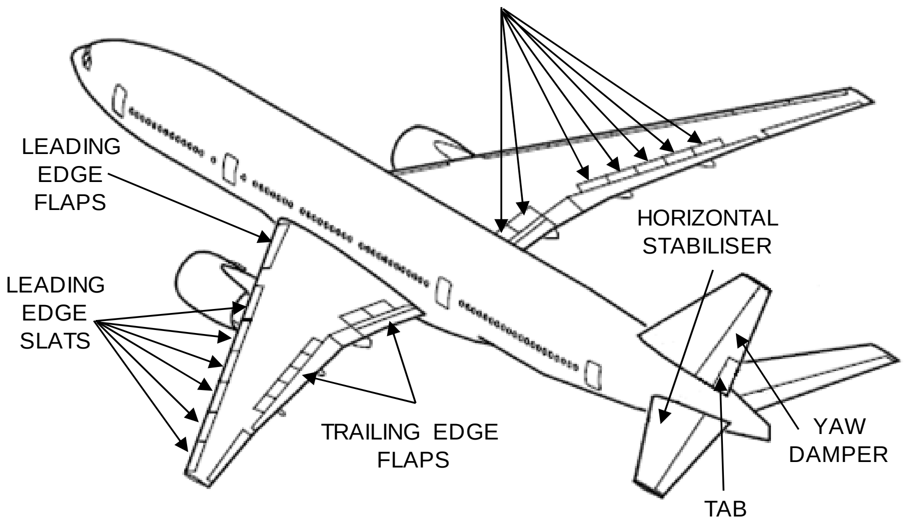


Figure 5-2 Secondary Flight Controls

Additionally, some primary flight controls such as ailerons may act as secondary controls for landing creating another flight control known as a flaperon (flap/aileron).

In almost every aircraft all of the secondary flight controls are powered.

PRIMARY FLIGHT CONTROLS

Primary flight controls are designed to enable the aircraft in all configurations and CofG positions and to manoeuvre around its three axes. The three axes are referred to as the;

- the Longitudinal Axis,
- the Lateral Axis, and
- the Normal or Vertical Axis.

Rotation around the Longitudinal Axis is called rolling and is controlled by the ailerons. Some aircraft augment rolling by co-ordinated spoiler operation.

Rotation around the Lateral Axis is called pitching and is controlled by the elevators. Some aircraft augment pitching by co-ordinated horizontal stabilizer operation. Supersonic aircraft will use pitch dampers for pitch control as well.

Rotation around the Normal Axis is called yawing and is controlled by the rudder. Some aircraft augment yawing by co-ordinated yaw damper operation.

The rotation around an axis is achieved by changing the aerodynamic force on the appropriate wing, horizontal or vertical stabilizer. Refer to Figure 5-3. Depending on the design of the aircraft this may be achieved by;

- changing the camber of the aerofoil
- changing the angle of attack (incidence) of the aerofoil, and/or
- decreasing the aerodynamic force by spoiling the airflow

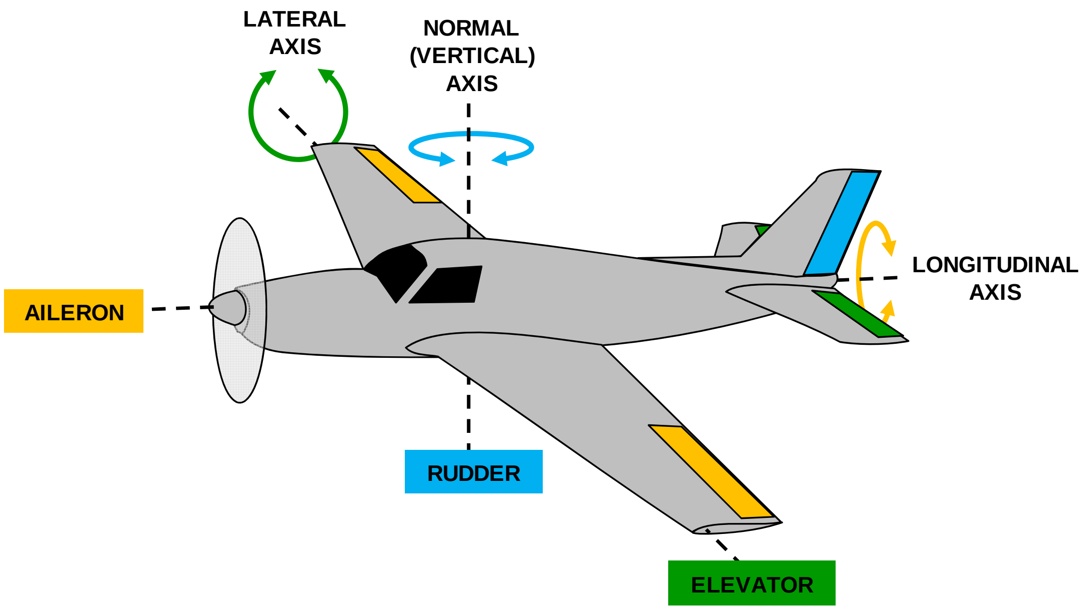


Figure 5-3 Aircraft Axes and Controls

SECONDARY EFFECTS

The three manoeuvres described, ROLLING, PITCHING and YAWING are known as the primary effects of the flight controls, however secondary effects occur to the aircraft when these manoeuvres are conducted. For example;

- When a ROLL manoeuvre is conducted the aircraft will tend to yaw in the opposite direction due to increase drag on the upgoing wing. This may be corrected by the use of Differential ailerons or Frise ailerons
- When a PITCH manoeuvre is conducted the aircraft will gain or lose airspeed due to changes of attitude.
- When a YAW manoeuvre is conducted the aircraft will tend to roll in the same direction due to increased lift on the faster wing.

Depending on the type, size and speed of the aircraft the primary flight controls will be either unpowered, using pilot force to move the control surfaces, or powered, using hydraulic force to move the control surfaces.

The following text and diagrams describes unpowered flight control systems. Powered flight control systems will be described later in this chapter.

MANUAL PRIMARY CONTROLS

INTRODUCTION

Primary flight control systems on light aircraft are purely mechanical and depend entirely on the force provided by the pilot to deflect the control surfaces. Mechanical controls may be operated by control rods or cables or combination configurations. There is normally only one set of control mechanisms (cable runs) for each primary control. Refer to Figure 5-4.

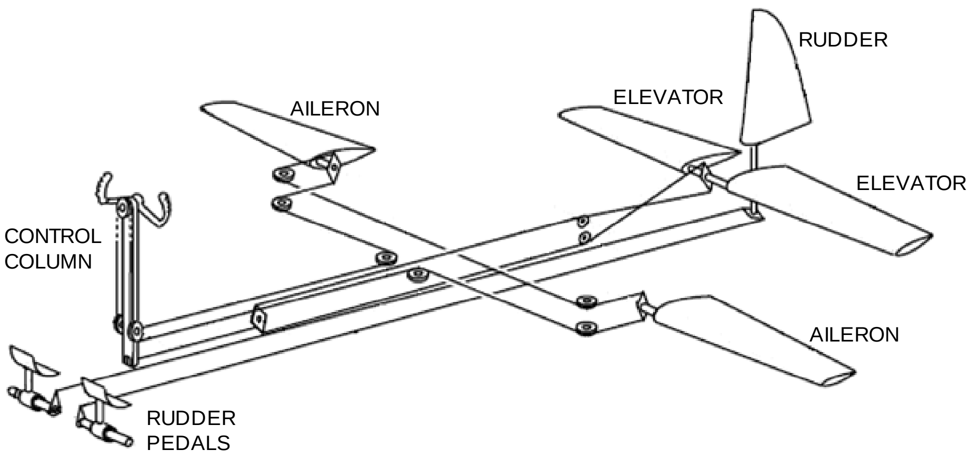


Figure 5-4 Cable Operated Primary Flight Controls

Because of this the flight controls will be designed with the following requirements and features;

- the flight control surfaces must be **balanced** to assist the pilot,
- they will have a **natural aerodynamic feel** when operated,
- they must have maximum **limits of deflection** to protect the aircraft structure, and
- they will have to be **locked** when the aircraft is parked.

BALANCE

All unpowered flight control surfaces are designed so that the force applied by the pilot will be sufficient to overcome the aerodynamic loads and fully deflect the surface if required. Additionally, unpowered flight controls should be stable and smooth in operation and have no bad operating characteristics.

To enable this, control surfaces are balanced by the following commonly used methods. They are;

- mass balancing,
- inset hinge point, and
- horn (aerodynamic) balancing,
- internal (aerodynamic) balancing,
- balance, anti-balance and spring tabs, and
- servo tabs.

Mass Balancing is simply applying a weight forward of the hinge axis to balance the weight of the control surface. This is common to all unpowered flight controls and it prevents "aerodynamic flutter" of the control surface in flight. Refer to Figure 5-5.

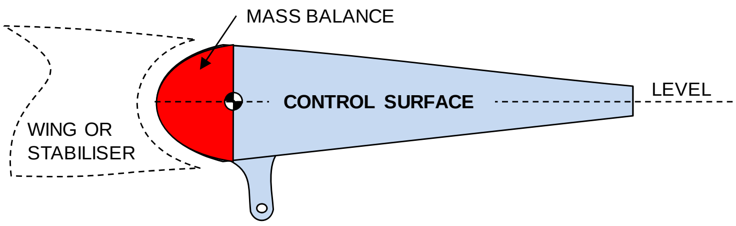


Figure 5-5   Mass Balance

The Inset Hinge is used to reduce the distance of the hinge point from the centre of lift acting on the control surface. This reduces the moment distance and the force required by the pilot to overcome the aerodynamic force acting on the surface. Refer to Figure 5-6.

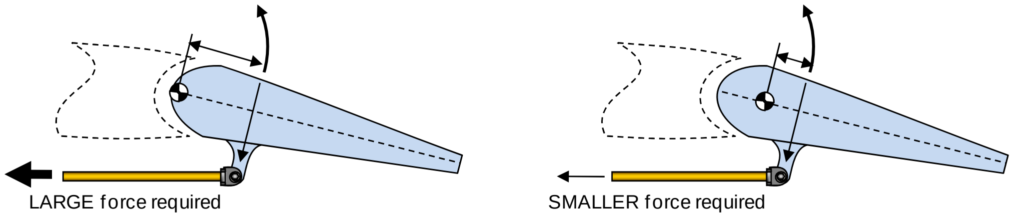


Figure 5-6 Inset Hinge

Horn Balancing provides a method of aerodynamic assistance to the pilot when the control surfaces are deflected. A protruding horn located forward of the hinge point enters the airstream and assists in moving the control surface. Horn balances can be shielded or unshielded. Refer to Figure 5-7.

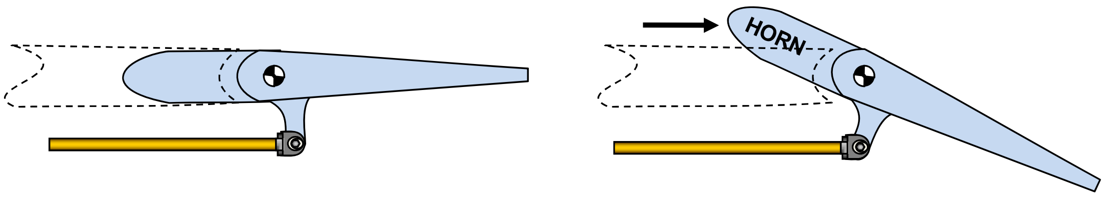


Figure 5-7 Horn Balance

Internal Balancing is achieved by installing a flexible seal between the leading edge of the control surface and the trailing edge of the wing or stabilizer. When the control surface is deflected the resultant difference in air pressures act upon the internal seal and assist the pilot in deflecting the control surface. Refer to Figure 5-8.

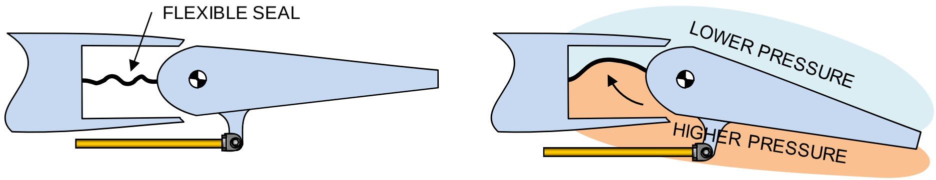


Figure 5-8 Internal Balance

Balance Tabs are small aerofoils fitted to the trailing edge of the control surface rather like trim tabs. They are mechanically geared to the flight control so that when the control surface is deflected by the pilot the balance tab automatically moves to assist the pilot aerodynamically. Refer to Figure 5-9.

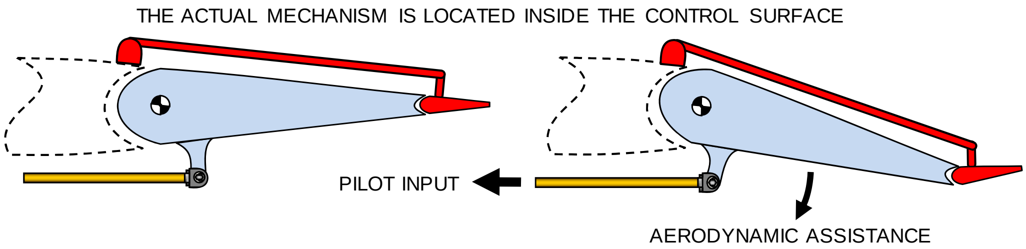


Figure 5-9 Balance Tab

Anti-Balance Tabs are the opposite too the balance tab and are geared to move in the same direction as the control surface. This increases flight control effectiveness but will of course result in heavier stick forces.

Spring Tabs are modified balance tabs. They include a spring in the mechanism which makes tab movement proportional to applied stick force. Maximum assistance is obtained when stick forces are greatest. The spring tab is used to reduce the higher control loads at high airspeeds. Refer to Figure 5-10.

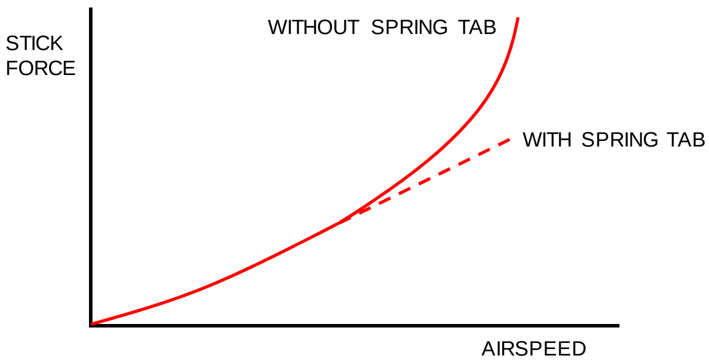


Figure 5-10 Control Load with Spring Tab

Servo Tabs are similar to balance tabs and are also fitted to the trailing edge of the control surface. However they are directly operated by the pilot using the normal control column. The servo tab can generate enough aerodynamic force to deflect the larger control surface which in turn causes changes to the aircraft attitude. Servo tabs were used on large aircraft before powered flight controls were developed. Refer to Figure 5-11.

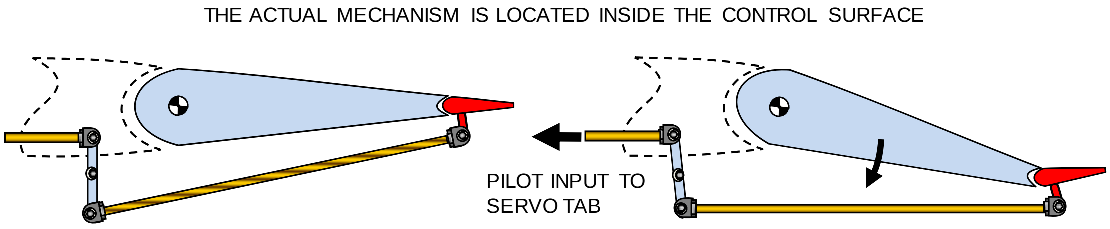


Figure 5-11 Servo Tab

NATURAL AERODYNAMIC FEEL

Unpowered flight controls are reversible. That is, a force applied to the cockpit control will move the control surface, and also, a force applied to the control surface will cause the cockpit control to move. This means that the air pressure on the control surfaces is felt by the pilot through the cockpit controls.

DEFLECTION LIMITS

Unpowered primary flight controls have two sets of mechanical stops to limit the maximum angle that a control surface can be deflected. The PRIMARY STOPS are located at the control surface and are contacted first. The SECONDARY STOPS are located at the cockpit controls.

CONTROL LOCKS

Aircraft that have unpowered flight controls require control or gust locks to be fitted when the aircraft is parked. Wind gusts can deflect the control surfaces and cause damage to the flight control system. Control locks make take the form of a simple inserted pin or a metal bar fitted to the control column in the cockpit, or clamps applied to the control surfaces.

<u>All control locks must be fitted with red streamers indicating they must be removed before flight</u>. Refer to Figure 5-12.

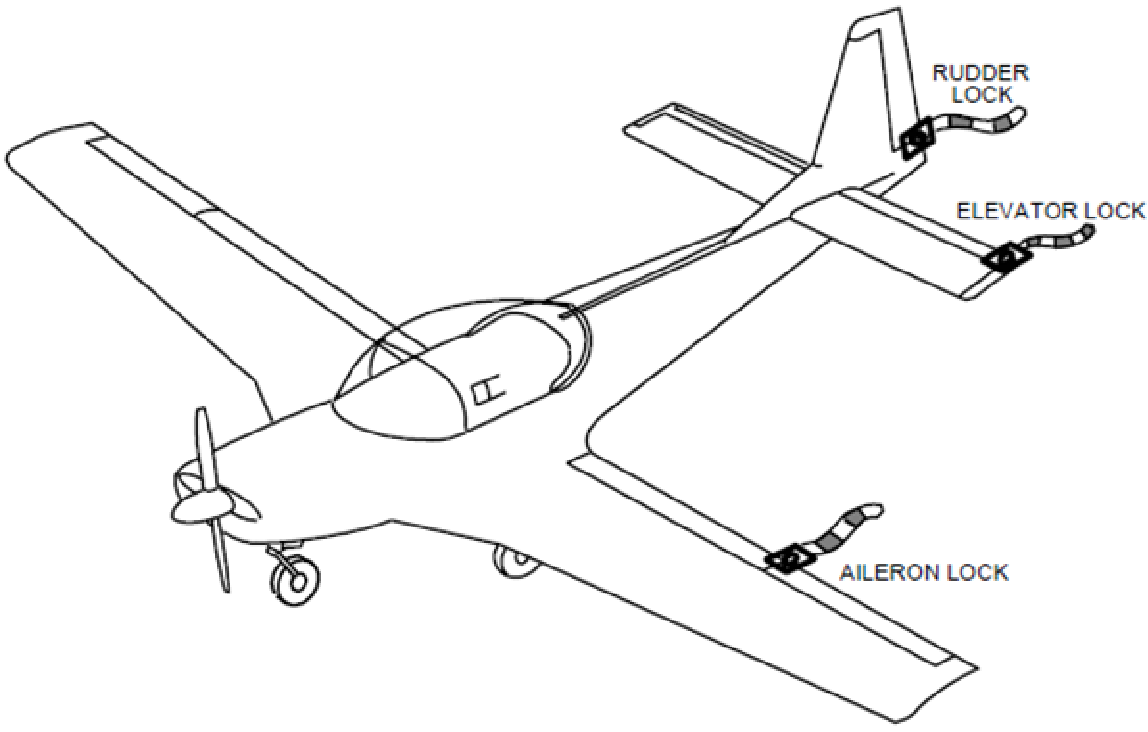


Figure 5-12 External Control Locks

PARTIALLY POWERED PRIMARY CONTROLS

Due to the size of control surfaces and the aerodynamic loads associated with medium to large aircraft the operation of the primary flight controls is beyond manual control and must be assisted using hydraulic power. The diagram below illustrates how a hydraulic actuator can apply a boosted force to the control surface. The pilot is still actuating the control surface and therefore is able to feel the aerodynamic load. This is a reversible flight control system. Refer to Figure 5-13.

In the event of a hydraulic failure, the power assisting actuator remains stationary, and the pilot reverts to direct manual operation of the controls, which obviously will be much harder to operate. Systems like this are not capable of handling the increased hinge moments on large aircraft flying at increasing airspeeds high and altitudes due to Mach effect.

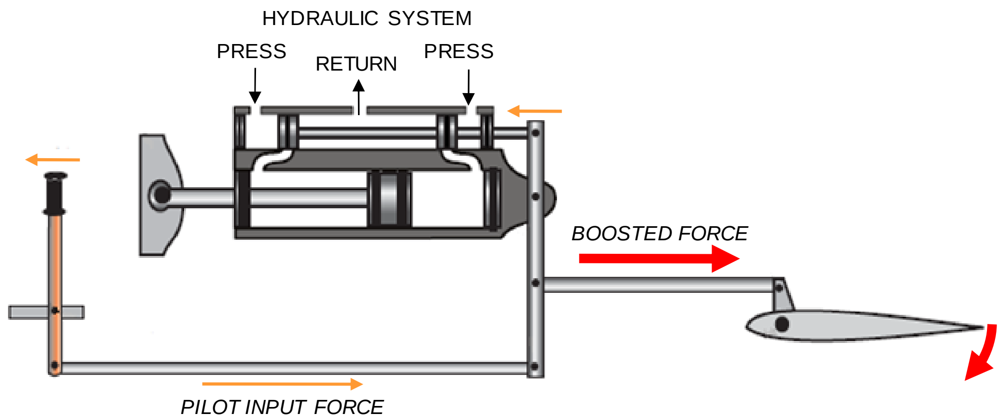


Figure 5-13 Partially Powered Flight Control

FULLY POWERED PRIMARY CONTROLS

INTRODUCTION

Fully powered flight controls are used on almost all modern medium to large aircraft. They are fully powered by hydraulic actuators, typically at pressures of 3000 PSI. Compare the diagrams in Figures 5-13 and 5-14 and note that in the fully powered flight control system the pilot only operates the actuator.

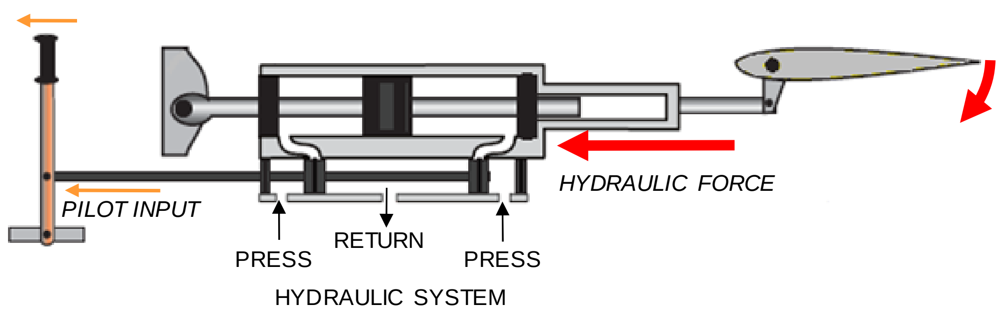


Figure 5-14 Fully Powered Flight Control

Some mechanical or electrical connection is still required from the pilot to the hydraulic actuators and depending on the aircraft type the connection may be configured as shown in Figure 5-15. Flight control systems such as these are irreversible and therefore require some form of artificial feel.

The mechanical connections between the cockpit controls and the hydraulic actuators are usually cable/control rod combinations and are always duplicated in case one connection jams. The electrical connections have multiple computers and electrical pathways for redundancy.

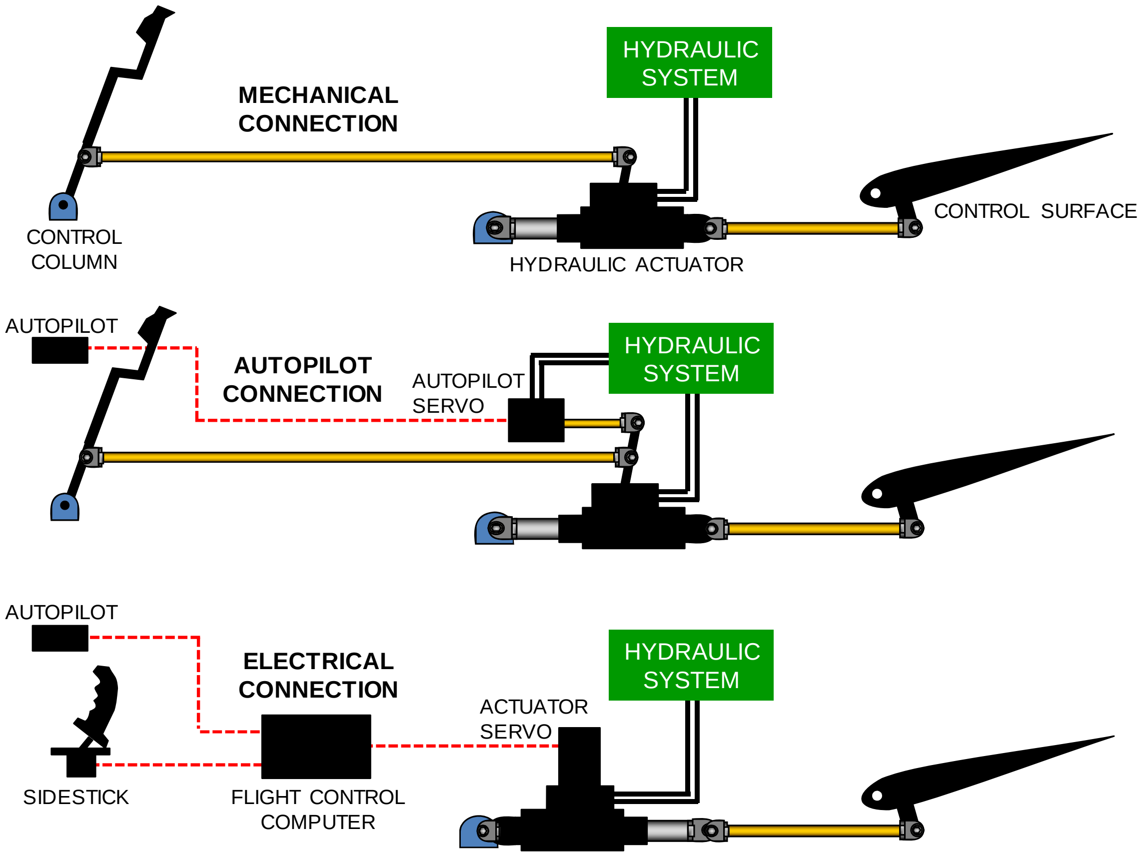


Figure 5-15 Fully Powered Flight Control Configurations

Fully powered flight controls will be designed with the following requirements and features;

- the flight control system must have **triple redundancy** of control surface operation,
- the **control connection** between the cockpit and the actuators **has redundancy**,
- flight control surfaces <u>may be balanced</u> to assist the hydraulics,
- they will have an **self centering device** when controls are released,
- they will have a **variable artificial feel** which changes with airspeed and load factor,
- they must have maximum **limits of deflection** to protect the aircraft structure, and
- they must have **variable limits** of deflection to protect the structure at high airspeed.

With the introduction of "fly by wire" aircraft most of the requirements and features listed are integrated functions of the Flight Control Computer and therefore do not require many of the components described in the following text.

TRIPLE REDUNDANCY

To ensure continued operation of the primary flight controls when malfunctions occur, large aircraft must be designed with triple redundancy. Flight control redundancy may be achieved by;

- operating control surfaces by three separate hydraulic systems simultaneously,
- operating split control surfaces by three separate hydraulic systems simultaneously, or
- operating control surfaces by two separate hydraulic systems simultaneously and including the capability to revert to manual unpowered operation if required.

Refer to Figure 5-16.

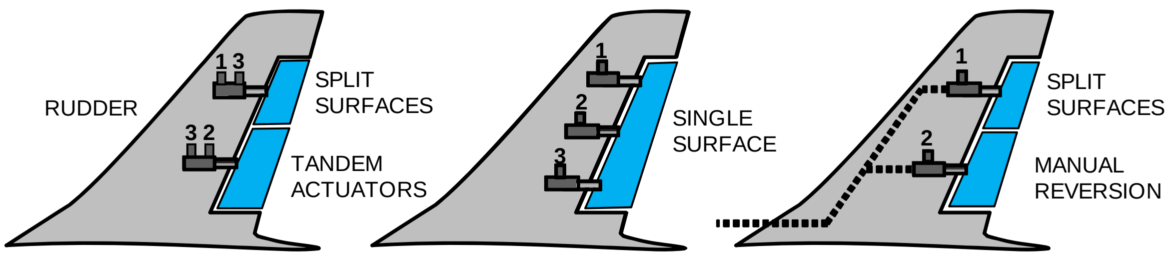


Figure 5-16 Flight Control Redundancy

Manual reversion can be achieved by mechanically disconnecting the hydraulic actuator from its attachment to the aircraft structure. The actuator becomes just another part of the linkage between the pilot and control surface. Operation of the controls is quite difficult due to the increased loads. Modern aircraft use triple hydraulic systems rather than manual reversion.

As previously detailed in Chapter 3, Hydraulic Systems, each individual hydraulic system will typically have at least two pumps available for pressure production.

Most modern aircraft now include a Ram Air Turbine (RAT) in one of the hydraulic systems as further protection against total engine or electrical failures. Refer to Figure 5-17 for an example aircraft flight control hydraulic configuration.

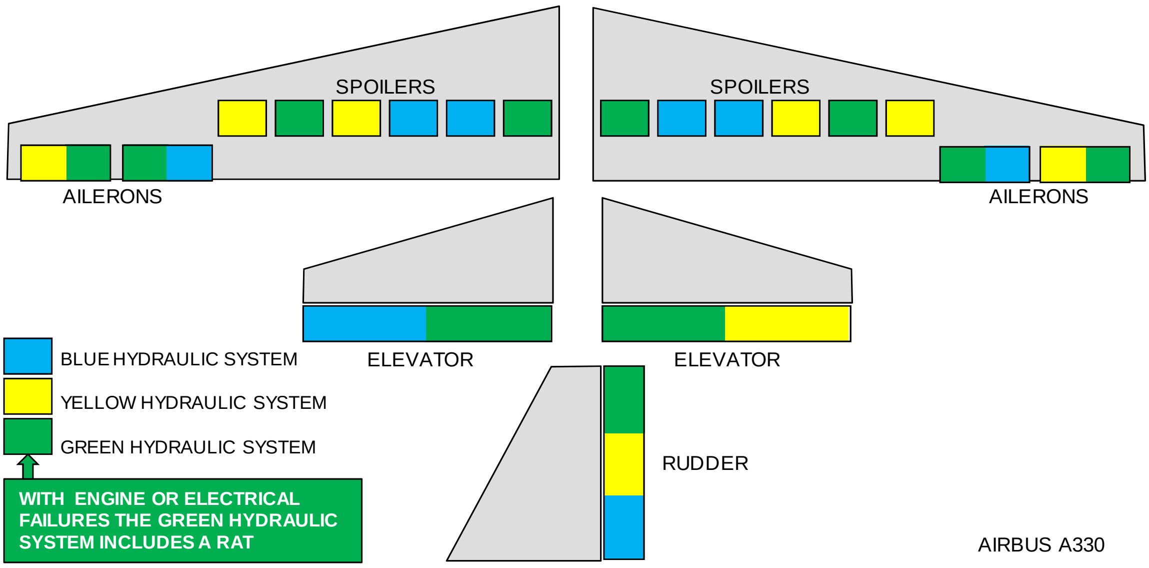


Figure 5-17 Modern Flight Control Configuration

CONTROL CONNECTION

The methods used to connect the cockpit controls to the hydraulic actuators powering the flight control surfaces are either;

- purely mechanical using cables and control rods, or
- purely electrical using computer assisted control.

Autopilots, when engaged in either system, connect electrically.

In purely mechanical mechanisms there are typically two cable/rod mechanisms connecting each pilot directly to the actuator controls. Both pilot controls are interconnected at the cockpit so that both cable/rod sets operate together. If a control jam occurs, either pilot (using more force) can break the interconnection and operate the free cable/rod mechanism.

The device that allows the disconnection is called a Control Override Unit, Load Limiter or Column Override.

For interest refer to the example B747-400 checklist, Figure 5-18.

JAMMED OR RESTRICTED FLIGHT CONTROLS

Condition: **Jammed or restricted flight controls experienced in roll, pitch, or yaw.**

JAMMED OR RESTRICTED SYSTEM.......................................OVERPOWER

Use maximum force, including a combined effort of both pilots, if required.

Do not turn off any flight control hydraulic power switch.

If freezing water is the suspected cause:

Consider descent to warmer air if conditions permit and reattempt to override the jammed or restricted controls.

If the faulty system cannot be overpowered:

Use operative flight controls, trim, and thrust as required for aircraft control.

Figure 5-18 Example Checklist for Jammed Controls

In purely electrical computer controlled connections there are normally at least two flight control computers simultaneously taking inputs from the pilots and directing controlling orders to the actuators. One computer normally becomes a master and the other(s) slaves on standby to automatically take over if required.

On most aircraft the pilot can control the computer configuration by switches in the cockpit. Refer to Figure 5-19.

Figure 5-19 Flight Control Computer Switches - Airbus

Each flight control computer is programmed with "LAWS or MODES" that control the operation of the flight controls to protect the aircraft from overstress and deviation from the aircraft's flight envelope. If certain malfunctions occur the flight control computers will automatically revert to DEGRADED laws or modes allowing the pilot to still fly the aircraft but with a loss of the envelope protections.

All aircraft that are computer controlled still retain some mechanically operated controls in case all electrical/computer control is lost. Refer to Figure 5-20.

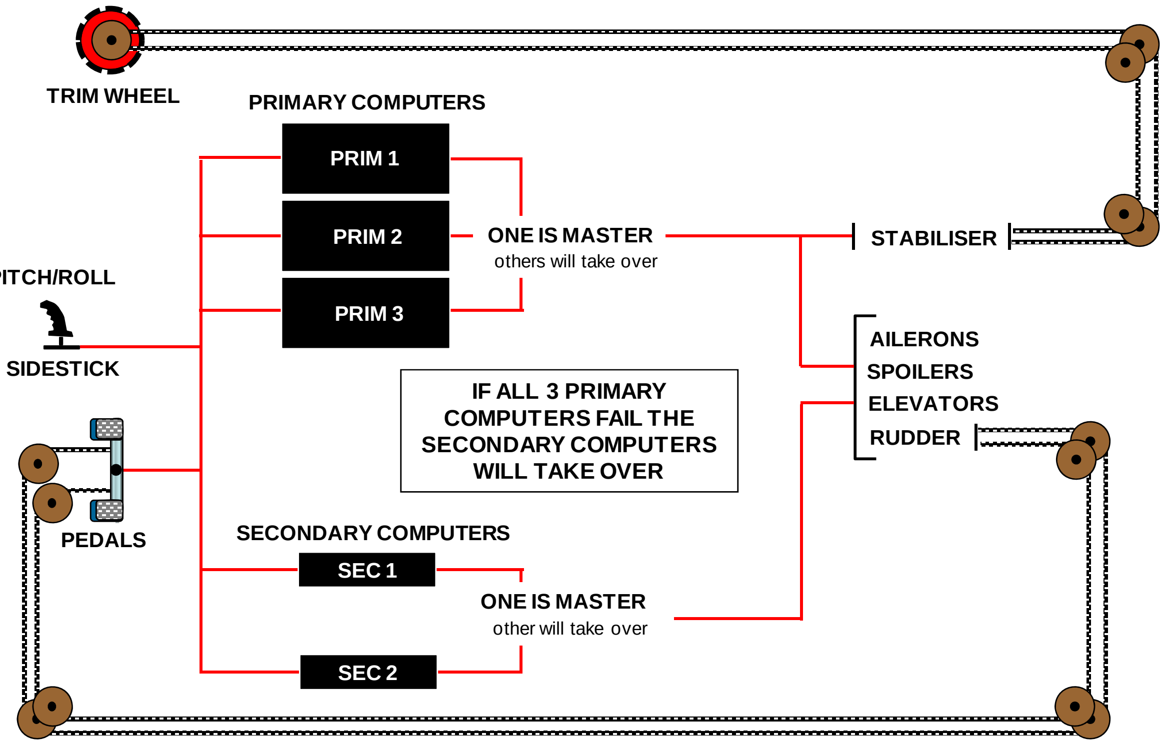


Figure 5-20 Flight Control Computer Configuration - Airbus

BALANCE

Unlike manual flight controls, fully powered flight control surfaces do not normally require the many balancing methods previously discussed. No pilot assistance is required with fully powered flight controls as they are positioned by hydraulic pressure and are irreversible. However, sometimes large control surfaces are balanced to reduce the hydraulic force needed to deflect them.

SELF CENTERING DEVICES

Hydraulically powered primary flight controls are irreversible and as such cannot be forced to a streamlined position by natural aerodynamic forces. An artificial method must be employed to “centre” the flight controls when pilot force is removed from the control column or rudder pedals.

In traditionally operated aircraft this is achieved by using opposing springs incorporated into the mechanical linkage from the control column to the hydraulic actuator. Refer to Figure 5-21.

In fly by wire aircraft control centering is accomplished by the Flight Control Computer (FCC) when the pilot releases pressure on the sidestick or rudder. The sidestick itself contains small springs internally which maintain the stick’s centered position.

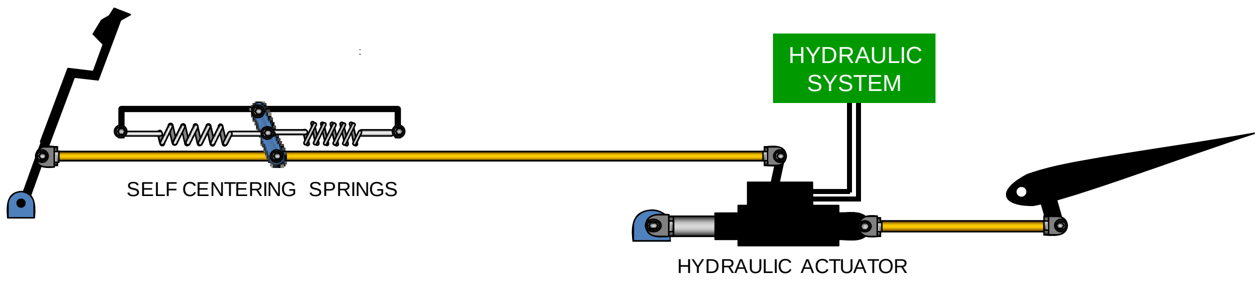


Figure 5-21 Flight Control Self Centering Device

The springs in a traditionally operated aircraft also act as an artificial feel for the pilot such that a gradually greater resistance is felt by the pilot as a greater deflection of the surface is made.

In modern Airbus aircraft the sidestick has no feel feedback to the pilot. The small springs within the sidestick will return it to the centre or neutral position, but this does not represent control feel. The Flight Control Computer is responsible to ensure that an excessive input by the pilot does not overstress the aircraft.

VARIABLE ARTIFICIAL FEEL

The artificial feel produced by the self centering springs described above is not sufficient to protect the aircraft from over control under all airspeed and air load conditions. Additional feel units are usually added to the control linkage to provide protections. They are;

- 'Q' feel units for increasing airspeed,
- 'g' feel units for increasing 'g' loading, and
- damper units for rapid control inputs.

'Q' Feel is a proportional increase of resistance to control movement as aircraft speed increases. The hydraulically operated unit proportionately resists movement of the control linkage in either direction as aircraft speed increases. Refer to Figure 5-21.

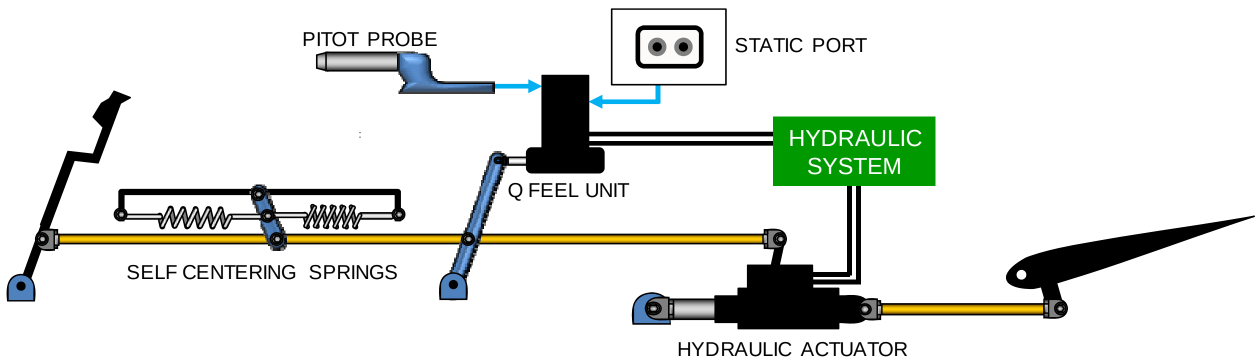


Figure 5-21 Increased Resistance with increasing Airspeed

These units are normally fitted to the elevator and rudder flight control linkages. Pitot pressure acts on the diaphragm against static pressure and as airspeed increases the dynamic pressure causes the servo valve to allow more hydraulic pressure to act on the resisting piston. The servo valve is dampened from rapid movement by allowing pressure to act on the bottom of the valve.

The piston proportionately resists movement of the control linkage in either direction as aircraft speed increases. Refer to figure 5-22.

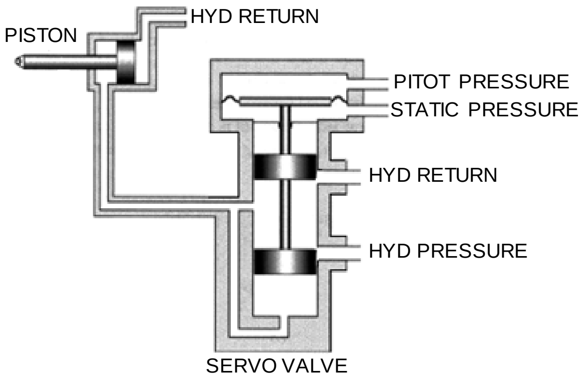


Figure 5-22 'Q' Feel Unit

'g' Feel is a proportional increase of resistance to control movement as 'g' load increases. These units normally use a weighted ball to increase resistance to the control input as the 'g' loading increases during a pitch manoeuvre on the aircraft.

Damper Units are incorporated to resist rapid control inputs. A simple piston displacing oil from one side to the other via a restricting orifice will dampen rapid control inputs by the pilot.

NOTE

In "fly by wire" aircraft the three protections described above are provided by the Flight Control Computer.

DEFLECTION LIMITS

Traditionally operated aircraft are similar to unpowered primary flight controls and have two sets of mechanical stops to limit the maximum angle that a control surface can be deflected. The PRIMARY STOPS may be located at the control surface or the hydraulic actuator and are contacted first. The SECONDARY STOPS are located at the cockpit controls.

In fly by wire aircraft mechanical stops are present at the flight controls or actuators but not at the side stick control.

VARIABLE DEFLECTION LIMITS

With a hydraulically powered rudder the maximum deflection angle has to be proportionately decreased as airspeed increases. A full rudder deflection at high airspeed would cause serious damage to the aircraft.

There are two methods used to vary the angle of deflection on traditionally operated aircraft. They are;

- rudder ratio limiting, and
- rudder power limiting.

Rudder ratio changer units are positioned in the mechanical linkage to the rudder to vary the angle of deflection for a fixed rudder input based on airspeed. These units are hydraulically powered and are designed to mechanically change the ratio between pilot input and rudder angle. Pitot pressure determines the change to the ratio. Refer to Figure 5-23.

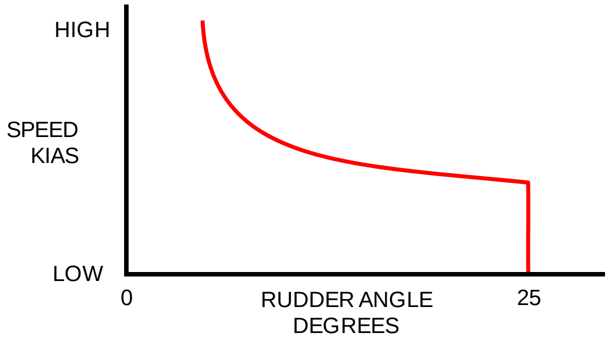


Figure 5-23 Airspeed versus Rudder Deflection Angle

If split rudder surfaces are used for redundancy each rudder surface will incorporate a ratio changer in its mechanism.

Rudder power limiting is not commonly used on modern aircraft as it involves shutting off one of the hydraulic systems that power the rudder.

At low airspeeds both hydraulic systems operate the rudder making full deflection available. At high airspeeds only one system powers the rudder making it impossible to achieve full deflection due to the increased air loads. Rudder power limiting may be triggered by airspeed or trailing edge flap position being up or not up.

NOTE

In "fly by wire" aircraft the rudder limiting described above is provided by the Flight Control Computer.

OTHER FLIGHT CONTROL DEFLECTION CHARACTERISTICS

Other flight controls besides the rudder have additional operating characteristics designed to enhance operation throughout the speed range of large jet transport aircraft. Ailerons are used in two ways which are;

- outboard aileron lockout at high speeds, and
- use as flaperons at low speed.

Outboard aileron lockout occurs at speeds of approximately 250-260 kts. All large jet transport aircraft are fitted with split ailerons referred to as the INBOARD and OUTBOARD ailerons. They work in conjunction with spoilers to optimize roll control at all airspeeds.

At low airspeeds BOTH ailerons operate together with the spoilers for roll control.

At high airspeeds the OUTBOARD ailerons are locked out of the control mechanism and remain at the streamlined position. The INBOARD ailerons are more than sufficient to roll the aircraft in conjunction with the spoilers.

The lockout mechanism is triggered by airspeed or trailing edge flap position being up or not up.

Flaperons is the term used to describe ailerons that deflect down to a new neutral position when landing flap is selected. By repositioning both the inboard and outboard ailerons in this way they act as additional flap surfaces. Obviously the ailerons continue to function as ailerons when in this position. Refer to Figure 5-24.

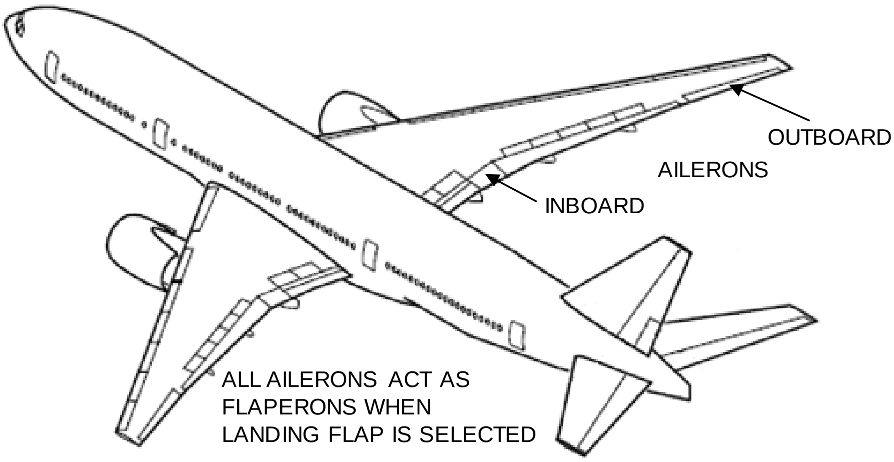


Figure 5-24 Typical Aileron Configuration

FLIGHT CONTROL INDICATIONS

On large jet transport aircraft the positions of the flight control surfaces are displayed in the cockpit allowing the full travel of each primary flight control to be checked before flight.

<u>Position sensors are fitted at each of the flight control surfaces and provide signals to the cockpit.</u>

It is unsafe to check the travel of the flight controls on pre-flight when the aircraft is surrounded by support staff and ground equipment and the flight control checks are normally carried during the taxi towards the take-off point,

Older aircraft display the flight control positions on a gauge typically located on the F/O’s forward panel but in modern aircraft they are displayed on a secondary page of the EICAS or ECAM. Refer to Figure 5-25.

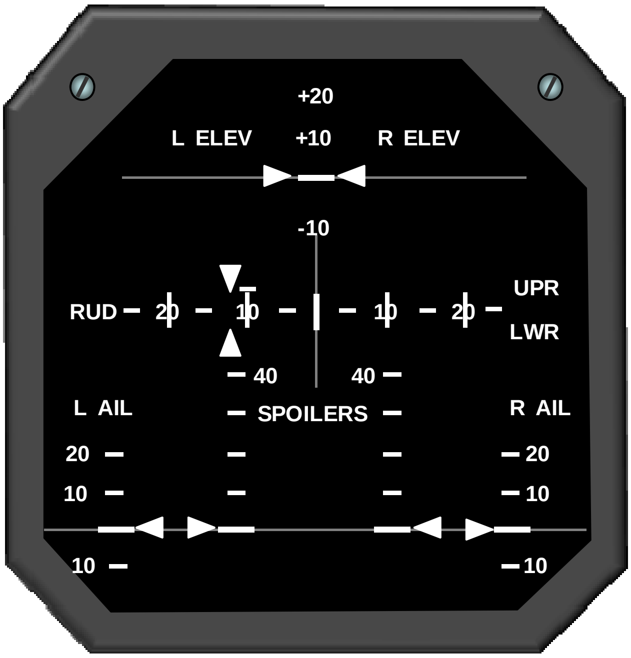


Figure 5-25 Flight Control Position Indicator - B747 Classic

FLIGHT CONTROL INPUT INDICATIONS

Obviously on aircraft with traditionally connected control columns, pilots can see and feel any control inputs made. On side stick controlled aircraft an indication of pilot input is displayed (overlaid) on both pilot Flight Directors.

This indication is only visible during the take-off and approach phases of flight. A white cross within a square box displays side stick inputs for pitch and roll. The edge of the box represents the maximum input that can be applied to the side stick. Refer to Figure 5-26.

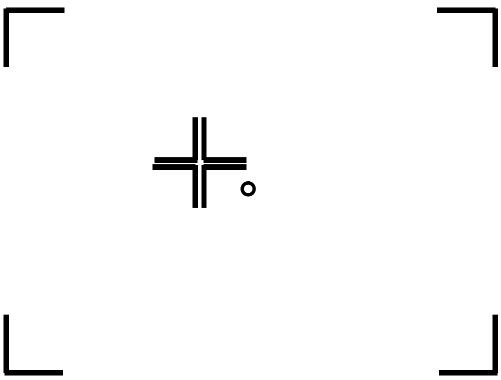


Figure 5-26 Side Stick Indications on PFD

FLIGHT SAFETY FEATURES AND FLIGHT ENVELOPE PROTECTIONS

Most aircraft of any size are fitted with a method of warning the pilot of an impending stall. Many light aircraft use a simple airflow sensor located on the leading edge of the wing to initiate a warning in the cockpit. On large jet transport aircraft the stall warning system is more complex and takes into consideration the position of the flaps, load factors and the air/ground position of the nose wheel. The airflow sensors used are called Angle of Attack (AoA) vanes and two are normally fitted, one on either side of the nose area near the pitot probes. Refer to Figure 5-27.

The AoA vane measures the relationship of relative airflow to the body angle of the aircraft and provides the information to the stall warning computers. The stall warning computer initiates a stall warning before a stall occurs. For interest at approximately 7% above the aircraft's stall speed.

Traditionally operated aircraft typically have a STICK SHAKER mounted on the control column which vibrates when a stall warning is initiated. Some aircraft also include a STICK NUDGER designed to push the control column forward if the pilot has ignored the stick shaker. The stall warning computers and stick shaker may be tested when the aircraft is on the ground during preflight.

In fly by wire aircraft the flight control computers continuously monitor and protect the limits of the aircraft's flight envelope and will not allow excessive pitch or roll angles and load factors. Therefore, a stall will only become impending when thrust is reduced and airspeed decreases.

If this occurs Airbus aircraft initiate a warning to the pilot called a LOW ENERGY warning which means that the aircraft energy has become lower than a threshold under which to recover a positive flight path angle through pitch control, and thrust must be increased.

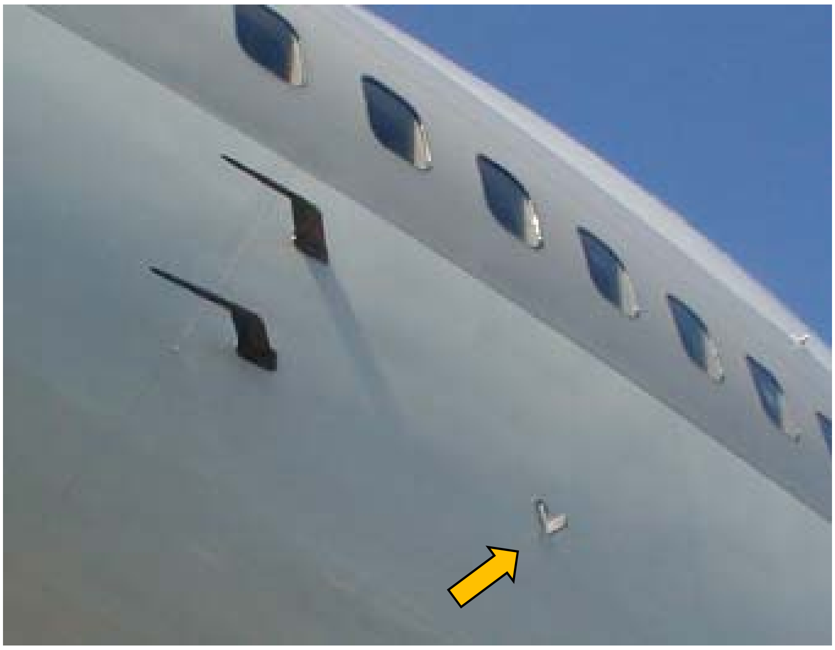


Figure 5-27 AoA Sensor (Vane)

SUMMARY OF PRIMARY FLIGHT CONTROLS

Primary flight controls can be of three types, manual, partially powered, and fully powered.

Manual and partially powered controls are reversible unlike fully powered which are irreversible.

Manual and partially powered controls have mechanical linkages from the cockpit controls to the control surfaces.

Manual controls have natural feel when operated and are not normally spring loaded to neutral. Control or gust locks are necessary for manual controls.

Partially powered controls have natural feel but are spring loaded to neutral and may require specialised units for ‘q’ and ‘g’ feel. Partially powered controls use hydraulic power to boost the pilot force applied. Partially powered controls can revert to manual control if hydraulic power is lost. Control or gust locks are necessary for partially powered controls.

Fully powered controls may be mechanical or ‘fly by wire’ and are powered hydraulically. Large aircraft must have triple redundancy for fully powered flight controls and this may be accomplished by;

- Using two separate hydraulic systems simultaneously with manual reversion capability.(older aircraft)
- Using three separate hydraulic systems simultaneously, or
- Using three separate hydraulic systems simultaneously with partial manual reversion capability. (fly by wire aircraft)

Mechanical fully powered controls are connected from the cockpit to the flight control actuators by cables and/or rods with dual systems. Override units allow each control run to operate if a jam occurs. Self centering and artificial feel units are required for fully powered mechanical flight controls.

Fly by wire fully powered controls are connected from the cockpit to the flight control actuators by multiple electrical channels via multiple flight control computers. Pilot input is to the flight control computers. Based on air data inputs the flight control computers protect the aircraft from excessive pilot inputs or other protections previously provided by artificial feel units. Control or gust locks are not necessary for fully powered controls.

SECONDARY FLIGHT CONTROLS

INTRODUCTION

Secondary flight controls are designed to reduce pilot workload, enhance the operation of the primary controls and to provide additional lift at low airspeeds. The following are common secondary flight controls;

- trim systems,
- spoilers/airbrakes,
- yaw dampers, and
- lift augmentation devices.

Secondary flight controls on small aircraft are relatively simple and normally only include a trim system and trailing edge flaps. Secondary flight controls on large aircraft are more complex and have many variations in design. Lift augmentation devices and other control protection features are described later in this Chapter.

TRIM SYSTEMS

INTRODUCTION

Aircraft will usually need to be trimmed in <u>pitch</u> as a result of;

- changes to airspeed and/or thrust, and
- changes to C of G position and/or configuration.

Aircraft will usually need to be trimmed in <u>yaw</u> as a result of;

- changes to propeller torque, and
- asymmetric thrust on multi-engined aircraft.

Aircraft generally do not need trimming in <u>roll</u> unless an asymmetric configuration or a lateral displacement of C of G occurs. Trim systems and trimming methods can be described to suit two groups of aircraft, which are;

- small aircraft with UNPOWERED primary controls, and
- medium to large aircraft with POWERED primary controls.

TRIM SYSTEMS ON SMALL AIRCRAFT WITH UNPOWERED CONTROLS

An aircraft with unpowered primary flight control surfaces is said to be trimmed when it will maintain attitude and airspeed without the pilot having to apply any force to the cockpit controls. This of course reduces pilot workload in maintaining steady flight.

Pilot operated movable trim tabs are fitted to the trailing edges of the primary flight control surfaces to aerodynamically position the control surface and eliminate the pilot force required on the controls to maintain stable flight. Refer to Figure 5-28.

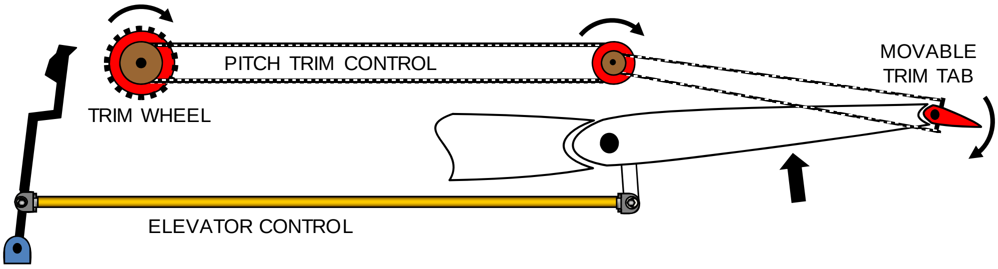


Figure 5-28 Pilot Operated Mechanical Trim Control

TRIM SYSTEMS ON LARGE AIRCRAFT WITH POWERED CONTROLS

Medium to large aircraft with powered primary flight controls do not require the use of trim tabs as discussed previously. Using the hydraulic power available the entire control surface can be positioned to trim the aircraft.

Medium sized transport aircraft usually trim all three primary control surfaces in this manner, however, most large transport aircraft use the horizontal stabilizer (instead of the elevators) for pitch trimming as very large trim changes will be required during the course of a normal flight. This is due to the consumption of the fuel carried in sweptback wings and/or horizontal stabilizers.

Trimming mechanisms can therefore be divided into two groups;

- trim mechanisms for aileron and rudder, (elevator on medium aircraft), and
- trim mechanisms for horizontal stabilizers on large aircraft.

Additionally, to enhance pitch trim operation in the cruise, some very modern aircraft such as the Airbus use the in flight transfer of fuel to maintain the aircraft's CofG at an ideal position. Fuel transfer for CofG position is discussed in Chapter 8, Fuel Systems.

Trim mechanisms for aileron and rudder on traditionally operated aircraft use an electric actuator to reposition the control linkage to the hydraulic actuator. This simply re-centers the flight controls to a trimmed position. The control wheel and rudder pedals will move when the respective trim motors are operated. Control of the electric actuator is achieved by electrical trim switches in the cockpit. This method is used for aileron and rudder trim (elevator on medium sized aircraft). Refer to Figure 5-29.

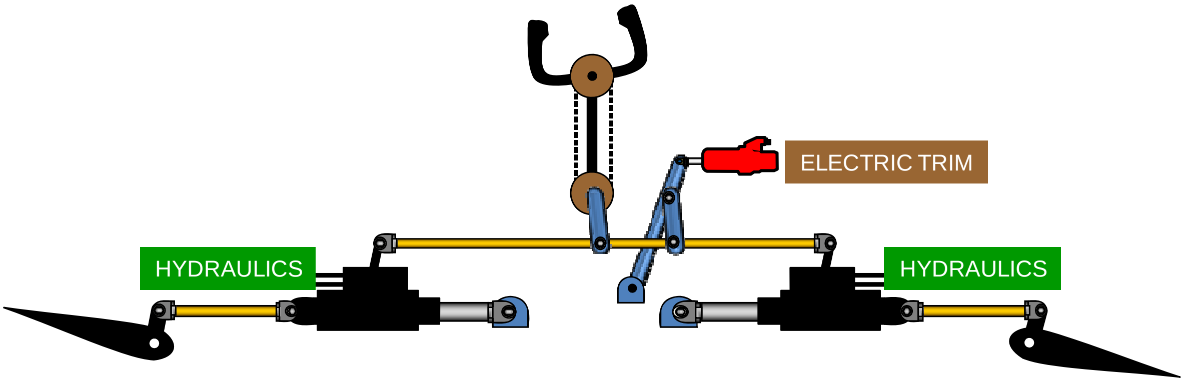


Figure 5-29 Typical Aileron Trim Configuration

Trim mechanisms for aileron and rudder in fly by wire aircraft are different as the flight control computer automatically maintains the aircraft in a trimmed condition by adjusting the control surface actuators. The sidestick and rudder pedals do not move when the respective flight control computers trim the aircraft. Aircraft such as the modern Airbus have no aileron trim control in the cockpit. A rudder trim switch is available for degraded operations of the normal rudder trim. Refer to Figure 5-30.

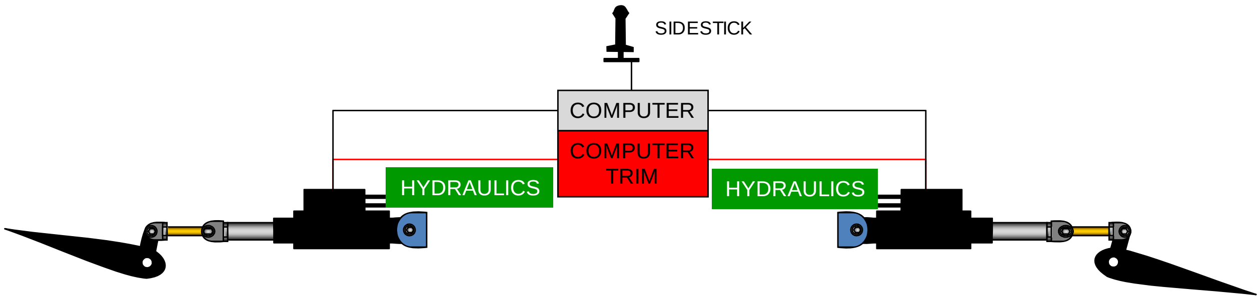


Figure 5-30 Typical Aileron Trim Configuration

Almost no trimming is needed for roll and yaw on large jet transport aircraft unless an engine failure occurs.

Trim mechanisms for PITCH trim on most large modern aircraft is accomplished by moving the horizontal stabilizer. As the horizontal stabilizer is a large and heavy surface it is moved hydraulically, not by linear rams but by hydraulic motors utilizing screw jacks and hydraulic brakes. Refer to Figure 5-31.

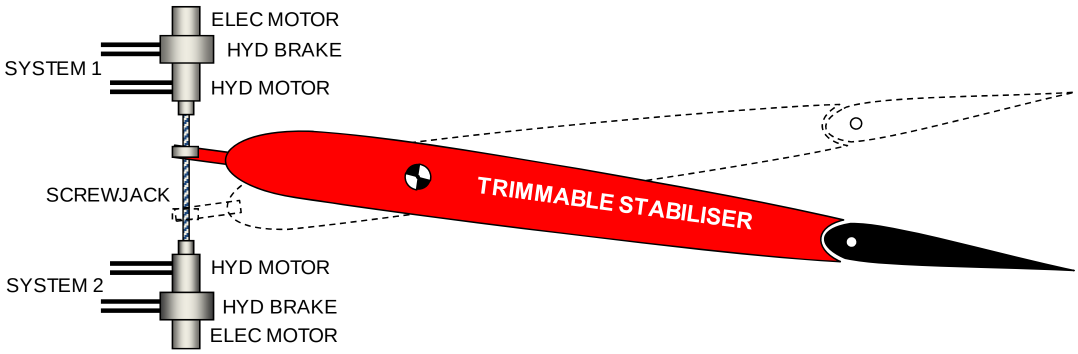


Figure 5-31 Horizontal Stabiliser Operation

The primary control (elevator) is controlled by the pilot and the horizontal stabilizer incidence is changed by the trim system. This configuration is referred to as a VARIABLE INCIDENCE TAILPLANE

Variable Incidence Tailplanes are the most commonly used method on large aircraft to provide pitch trim. Refer to Figure 5-32.

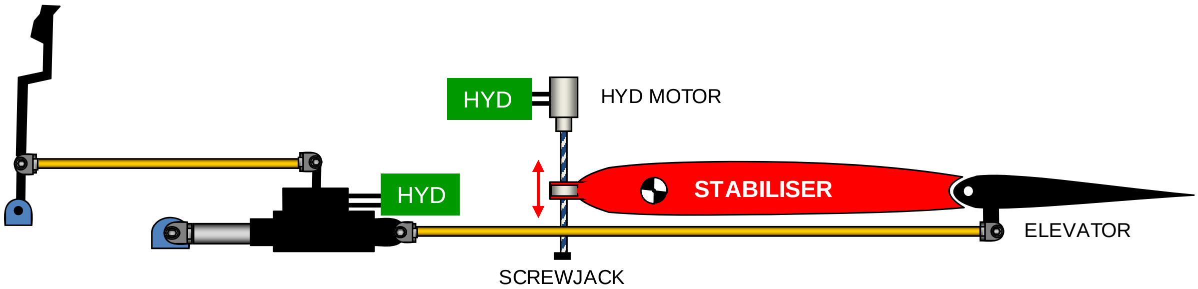


Figure 5-32 Variable Incidence Tailplane

The correct operation of the horizontal stabilizer is critical to the safe operation of the aircraft and is normally provided with ample hydraulic, electrical and sometimes mechanical redundancy mechanisms. For example with a total hydraulic and electrical system failure the horizontal stabilizer may still be moved using a mechanical hand wheel in Airbus aircraft. Refer to Figure 5-33.

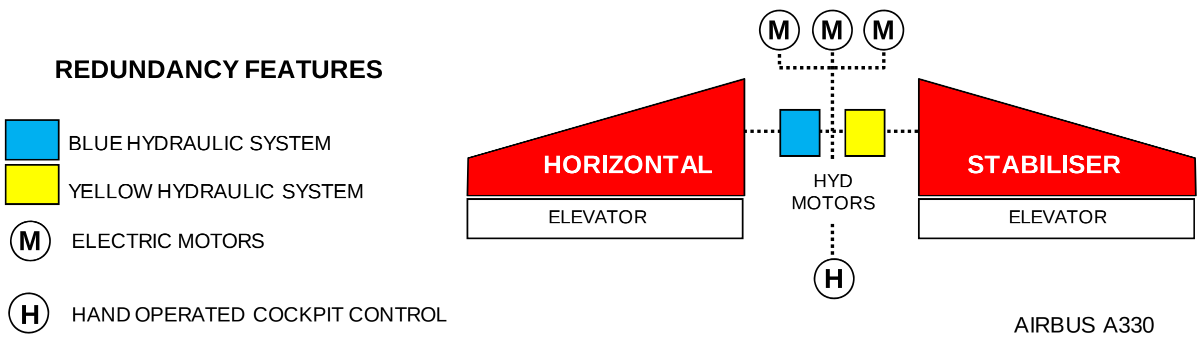


Figure 5-33 Horizontal Stabiliser Redundancy

Additionally, a horizontal stabilizer that malfunctions and continues to travel after movement should stop, presents a serious problem to the pilot. A "runaway stabilizer" will rapidly put the aircraft outside the range of pitch control provided by the elevators.

Trimmable stabilizers are fitted with hydraulic brakes and electrical and hydraulic cutout switches to prevent uncontrolled travel.

A variation of the moveable tailplane is called the ALL FLYING TAILPLANE. It is not commonly found in use today but should be described.

All Flying Tailplanes are not common on modern large jet transport aircraft. This configuration differs from the variable incidence type in that the horizontal stabilizer and not the elevator is directly controlled by the pilot. The elevator is connected to both the stabilizer and the aircraft structure.

When the pilot applies a pitch input the stabilizer is moved (as the primary control) and the elevator mechanically changes position to aerodynamically balance (resist) the movement of the stabilizer. This is the same principle as the anti-balance tab. Refer to Figure 5-34. Note that the stabilizer is trimmed by using the primary flight control mechanism.

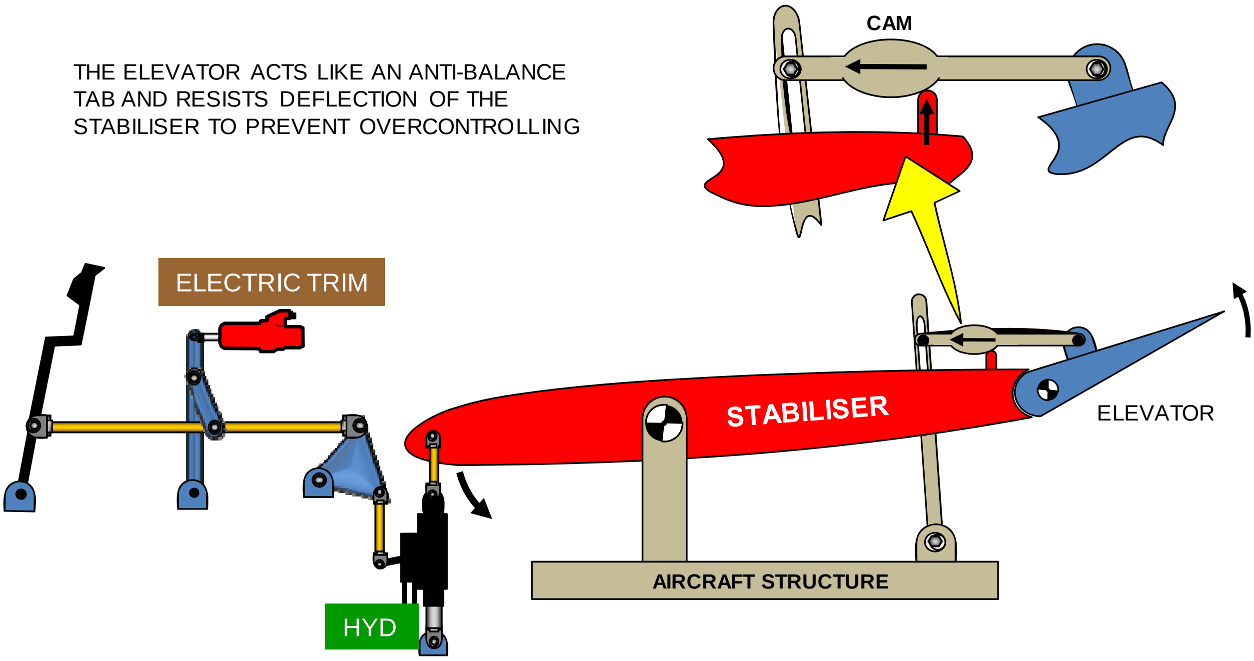


Figure 5-34 All Flying Tailplane

TRIM INDICATIONS

On light aircraft with mechanically operated trim tabs the position indication is typically a pointer geared to the control knob or wheel which moves across placarded markings adjacent to the trim control. Trim indication is important as it allows the pilot to set the correct trim prior to take-off.

On large aircraft with no trim tabs and trimming systems that displace the entire flight control mechanism, a dedicated mechanical or electrical indicator is provided.

On traditionally operated aircraft such as the Boeing range, trim position is displayed in the following manner;

- Aileron Trim – a placarded scale and mark on the top of each control wheel which indicates wheel displacement in degrees from neutral.
- Rudder Trim – a single electrically operated scale at the rear of the centre console adjacent to the rudder trim control indicating rudder displacement in degrees.
- Pitch Trim – an electrically operated scale for each pilot located on either side of the centre console indicating horizontal stabilizer displacement in degrees.

For interest many aircraft also provide a trim indication of the horizontal stabilizer on the external fuselage adjacent to the leading edge. Refer to Figure 5-35.

This provides a quick reference confirmation during preflight inspections that neutral pitch trim (0 units displayed in the cockpit) is also neutral at the surface.

Figure 5-35 External Pitch Trim Indication

The correct pitch trim setting is critical for the take-off on large transport aircraft and therefore the dual pitch trim indicators are monitored for loss of electrical power. Some aircraft provide a system which warns the pilot of an incorrectly set pitch trim for take-off.

This is called the stabilizer trim configuration warning system.

STABILISER TRIM CONFIGURATION WARNING

On aircraft fitted with this system the Flight Management Computer (FMC) uses entered CofG, AUW and take-off thrust to determine a range in which the pitch trim should be set. Pressure on the nose undercarriage leg is measured automatically and the system confirms the range determined by the FMC.

The predicted range is referred to as the "green band" and is displayed within the pitch trim indicator. Refer to Figure 5-36.

If the actual pitch trim set by the pilot is outside the "green band" a configuration warning is generated when the thrust levers are advanced for take-off.

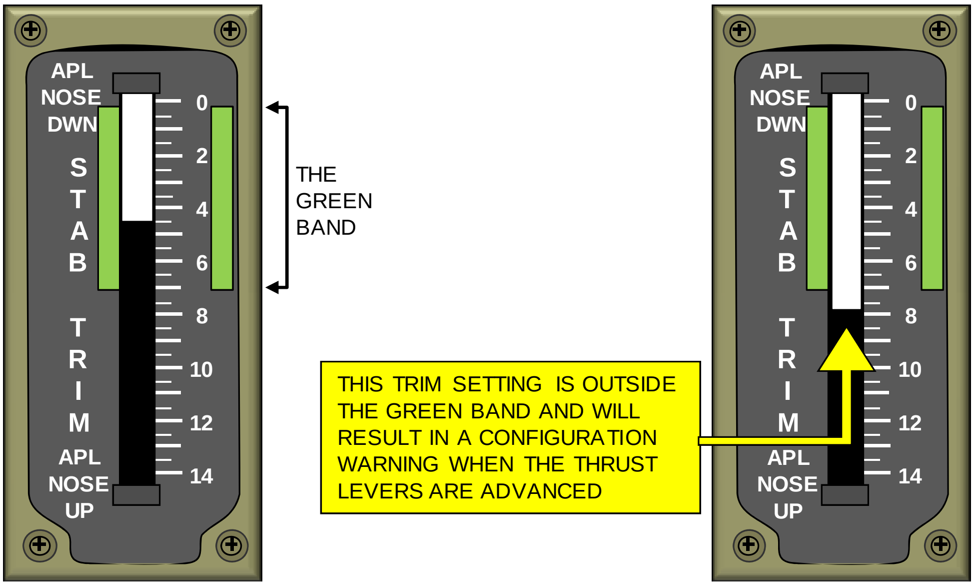


Figure 5-36 Pitch Trim Indicator and Green Band

TRIM CONTROLS

Light aircraft trim controls are normally mechanically operated however some modern light aircraft have electrical pitch trim fitted. Mechanical controls are typically a large wheel for pitch trim and smaller wheels or knobs for aileron and rudder. All of these mechanical controls are normally located on the centre console of two place aircraft.

Large jet transport aircraft normally locate the electrical aileron and rudder trim controls at the rear of the centre console within reach of either pilot. Pitch trim electrical controls for each pilot are typically positioned on one horn of each control wheel.

Fly by wire type aircraft are usually self trimming and any trim controls provided are only used if a malfunction of the automatic trim occurs.

On traditionally operated aircraft the trim controls are positioned in the following locations;

- Aileron Trim – at the rear of the centre console in the form of a set of double switches which must be operated simultaneously.
- Rudder Trim – at the rear of the centre console adjacent to the aileron trim in the form of a rotating mechanical knob or electrical switch.
- Pitch Trim – on one horn of each control column a set of double switches or a single switch. This position allows the pilot to maintain a grip on the column and operate the trim with the thumb.

Pitch trimming on large aircraft is normally conducted by moving the horizontal stabilizer and the control of pitch trim is more complex than the other trim systems.

Redundant control methods and safety features are required as the correct positioning of the horizontal stabilizer is critical to the safe operation of the aircraft. Refer to Figure 5-37.

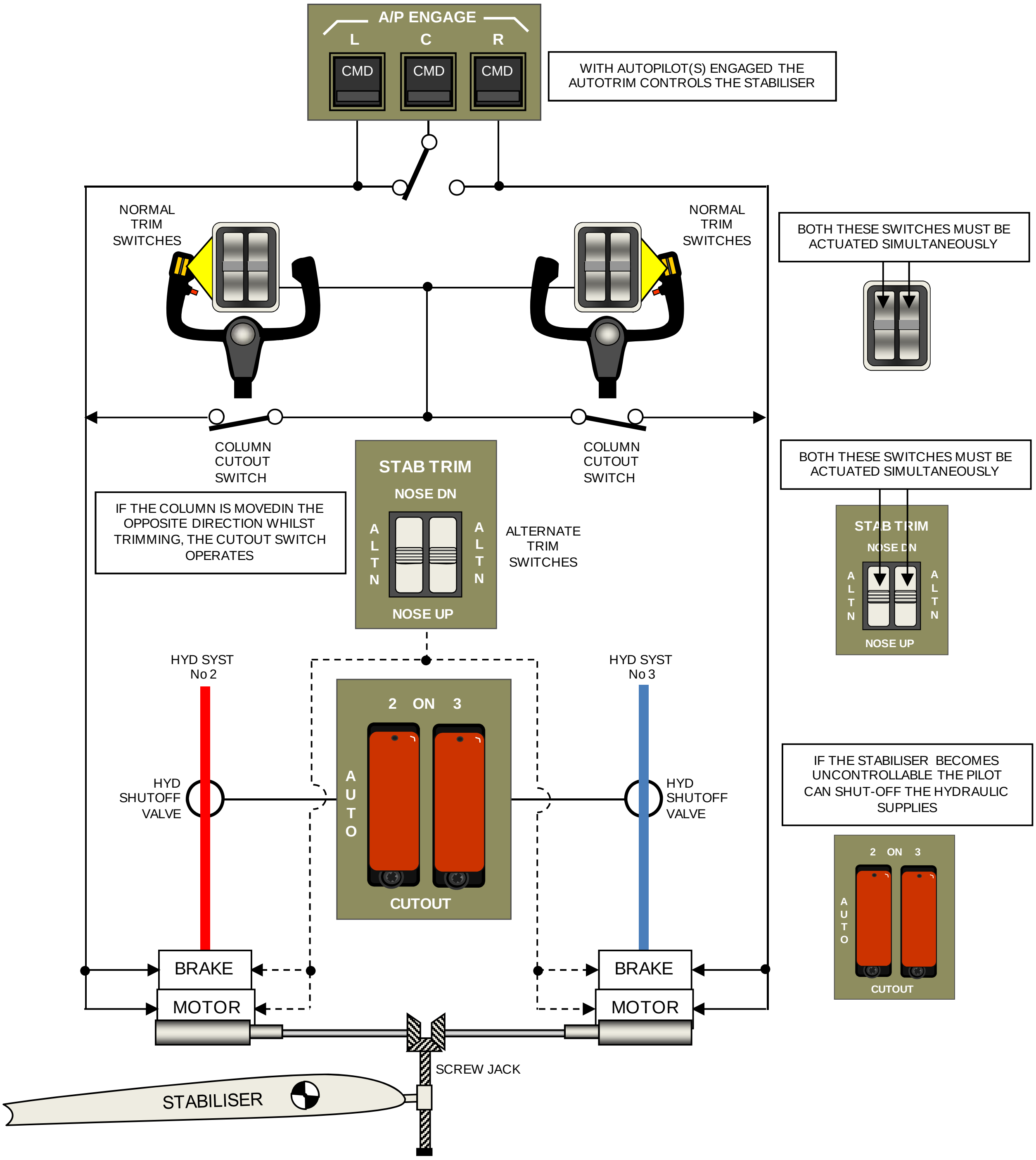


Figure 5-37 Pitch Trim Control – Redundant Features

SPOILERS/SPEEDBRAKES

Spoilers are flat panel control surfaces which are normally located on the top of the wing in front of the trailing edge flaps. Refer to Figure 5-38.

These surfaces are individually hinged at their leading edges and are actuated by individual hydraulic actuators. The main purpose of the surfaces is to disturb the smooth airflow over the top of the wing, thereby reducing lift, and when fully extended considerably increasing drag.

Spoilers are positioned so that aircraft pitch trim is not adversely affected by their deployment. Numerous spoiler panels are fitted on each wing and are typically numbered from left to right across the aircraft.

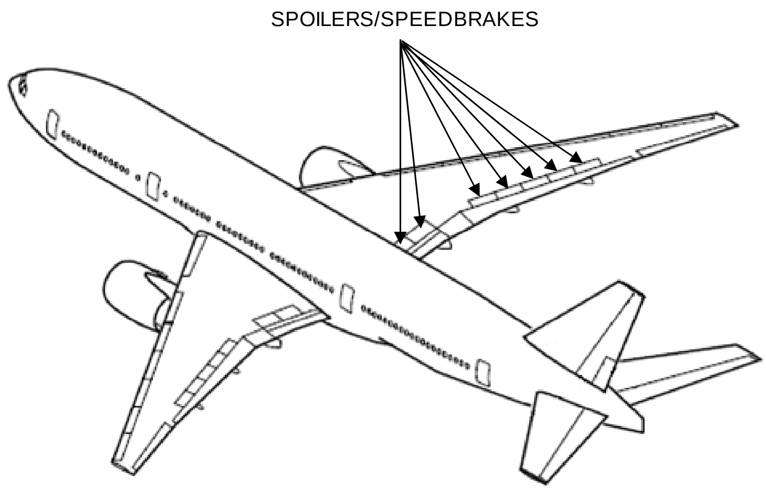


Figure 5-38 Spoiler Locations (Typical)

Spoilers are used to perform three functions which are;

- to assist the ailerons in providing roll control,
- as speedbrakes in flight to reduce airspeed, and
- as lift dumpers on landing to increase weight onto the landing gear improving the efficiency of the wheel braking action.

Different groups of panels deploy depending on the function they are performing.

Roll Augmentation using spoilers is common to all large jet transport aircraft. Spoilers are raised proportionately to aileron input on the down going wing to destroy lift. The spoilers on the up going wing remain retracted. Spoiler movement is initiated by roll input by the pilot. Not all of the spoiler panels are used for roll augmentation as their particular position may exert extra load on the wing structure. The spoiler panels used for roll augmentation are known as the FLIGHT SPOILERS.

Reducing Airspeed using the spoilers as speedbrakes is common practice in aircraft fitted with wing spoilers. Using a cockpit control the pilot may deploy spoilers symmetrically to reduce airspeed. Not all of the spoiler panels are used for speedbrakes as their particular position may create turbulence at the horizontal stabilizer. The spoiler panels used for reducing airspeed are known as SPEEDBRAKES. There are two important facts relating to speedbrake operation which should be noted. They are;

- when speedbrakes are deployed normal roll augmentation is still operable, and
- on some aircraft speedbrakes cannot be used once flaps have been extended.

Lift Dumping after landing using the spoilers is also common practice in aircraft fitted with wing spoilers. Provided main gears are on the ground and thrust is at idle all spoiler panels may be deployed to destroy wing lift. Initiating deployment may be done by the pilot at any time on the ground using the cockpit control, however normal initiation occurs automatically on touchdown. The spoiler panels (all) used for lift dumping are known as GROUND SPOILERS.

To co-ordinate the three functions described a spoiler mixer unit is used to operate the hydraulic actuators based on the inputs from the aileron controls, the speedbrake lever, and the ground/air sensing system. Refer to Figure 5-39.

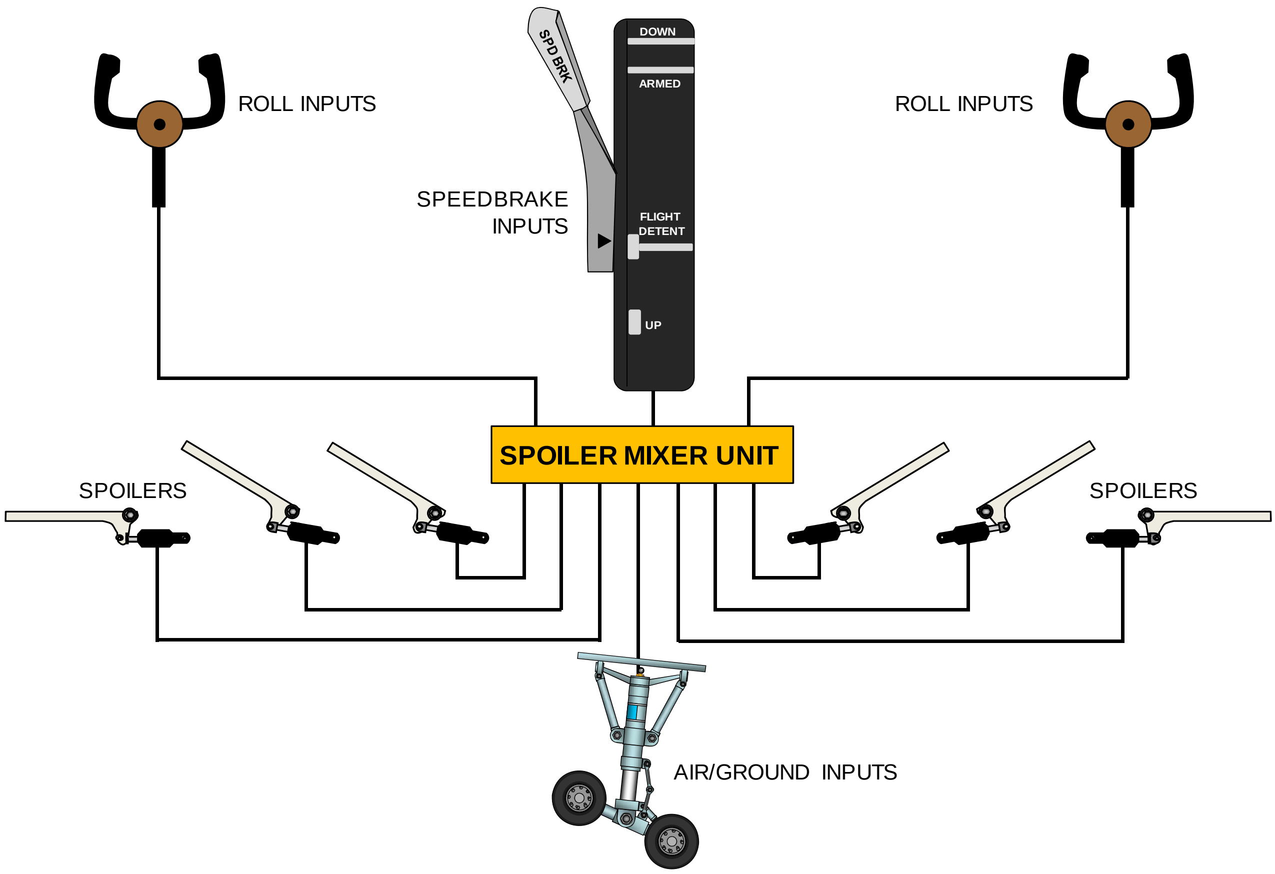


Figure 5-39 Spoiler Mixer Unit

SPOILER INDICATIONS

On large jet transport aircraft the positions of the spoiler surfaces are displayed in the cockpit allowing the operation to be checked before flight.

Position sensors are fitted at a flight spoiler panel on each wing and should provide indication simultaneously with aileron deflection.

Older aircraft display the spoiler and flight control positions on a gauge typically located on the F/O's forward panel but in modern aircraft they are displayed on a secondary page of the EICAS or ECAM. Refer to Figure 5-25.

SPEEDBRAKE AND GROUND SPOILER CONTROL

Typically located on the Captain's side of the centre console is the speedbrake or spoiler lever. The spoiler lever normally has three or four positions depending on the aircraft.

In most aircraft the lever is named the speedbrake lever and it has three positions, DOWN, ARMED and UP. Refer to Figure 5-40.

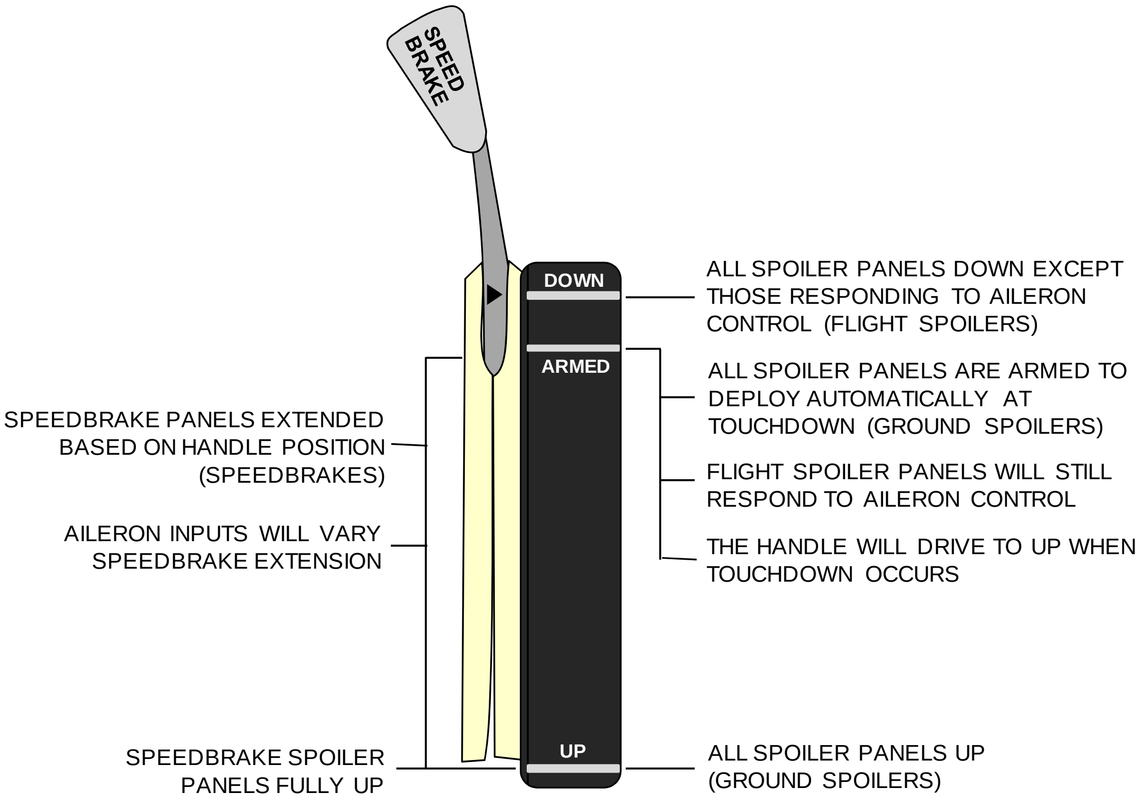


Figure 5-40 Speedbrake Lever

Inflight the pilot may deploy the speedbrakes to reduce speed or decrease descent rate. If turns are conducted whilst speedbrakes are deployed the speedbrake panels that are also flight spoilers will respond accordingly to roll inputs.

Prior to landing the the pilot will move the lever to the ARMED position and when;

- both main gears touchdown occurs, and
- thrust levers are at idle.

the lever automatically drives to the UP position deploying all spoiler panels (ground spoilers).

If at this point the pilot decides to abort the landing and take-off again he will obviously have to advance the thrust levers. When the thrust levers are advanced the lever will automatically drive to the DOWN position and retract the spoilers.

During take-off the lever is NOT armed, however, if an abort is conducted the handle will automatically drive to the UP position, deploying ground spoilers if reverse thrust is actuated.

Finally a further protection is provided to prevent ground spoiler deployment at excessive airspeed.

SPOILER BLOWDOWN

Although spoiler panels are hydraulically operated they are designed to be "blown down" as airspeed and thus airload upon them increases.

At low airspeeds with full aileron input the flight spoilers will be fully deployed. As airspeed increases spoiler blowdown will increase proportionately until a speed can be reached at which the spoilers are fully blown down. Refer to Figure 5-41.

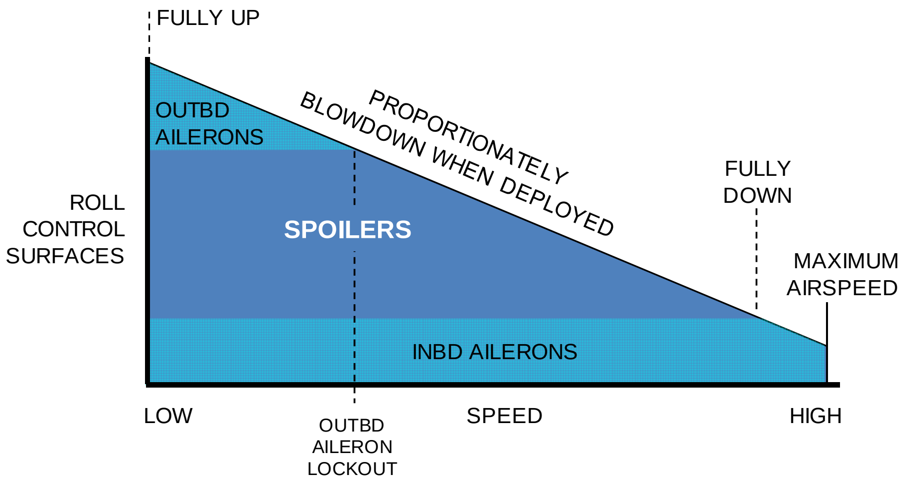


Figure 5-41 Spoiler Blowdown

SPOILER WALKDOWN

Aircraft that are not fitted with spoilers roll around the longitudinal axis as a consequence of aileron deflection. \When aircraft use spoilers for roll augmentation, the pivot point for the roll occurs near the out board flap area. As a consequence, continued opposite roll manouveres will result in a loss of height. This condition known as "spoiler walk-down" or "wing walk-down".

SPOILER EVACUATION OVERRIDE

Aircraft that are fitted with spoilers will typically have an override safety feature for the most inboard spoilers. This is designed so that in the case of a passenger evacuation with the spoilers still deployed, the inboard spoiler panels will be forced down, clearing the way for slide deployment over the wing. This safety feature is usually triggered by opening the overwing exit doors.

OTHER AIRBRAKES OR SPEED BRAKES

Military fighter types and some smaller commercial aircraft are fitted with specific speed brake panels which are only intended as a speed brake for use in the air and sometimes on the landing rollout.

Ideally the speed brake should produce an increase in drag with no loss of lift or change in pitching moment. A fuselage mounted speed brake is best suited to meet these requirements. They provide better low speed stability than when the aircraft is in a clean configuration.

Speed brakes are in addition to the wing spoilers used for roll augmentation and lift dumping. Refer to Figure 5-42.

Figure 5-42 Specific Airbrake fitted to BAe 146

YAW DAMPERS

Modern swept wing aircraft that fly at high cruising altitudes are fitted with automatic yaw dampers as part of their flight control system. There are normally two fitted working simultaneously. Yaw dampers are required to prevent "dutch role" which is discussed in the aerodynamics subject.

A rate gyro senses small changes in yaw due to external air forces and signals the yaw damper to move the rudder sufficiently to counteract the yaw. A hydraulically operated yaw damper actuator located in the mechanism to the rudder makes the required changes.

Yaw dampers are continuously monitored for correct operation and will display a failure light or alert when unserviceable. Yaw dampers have a cockpit control switch so that they may be turned OFF. There are two types of yaw damper systems which may be fitted. They are;

- parallel, which MOVES the rudder pedals when damping, and
- series, which DOES NOT MOVE the rudder pedals when damping.

Refer to Figure 5-43.

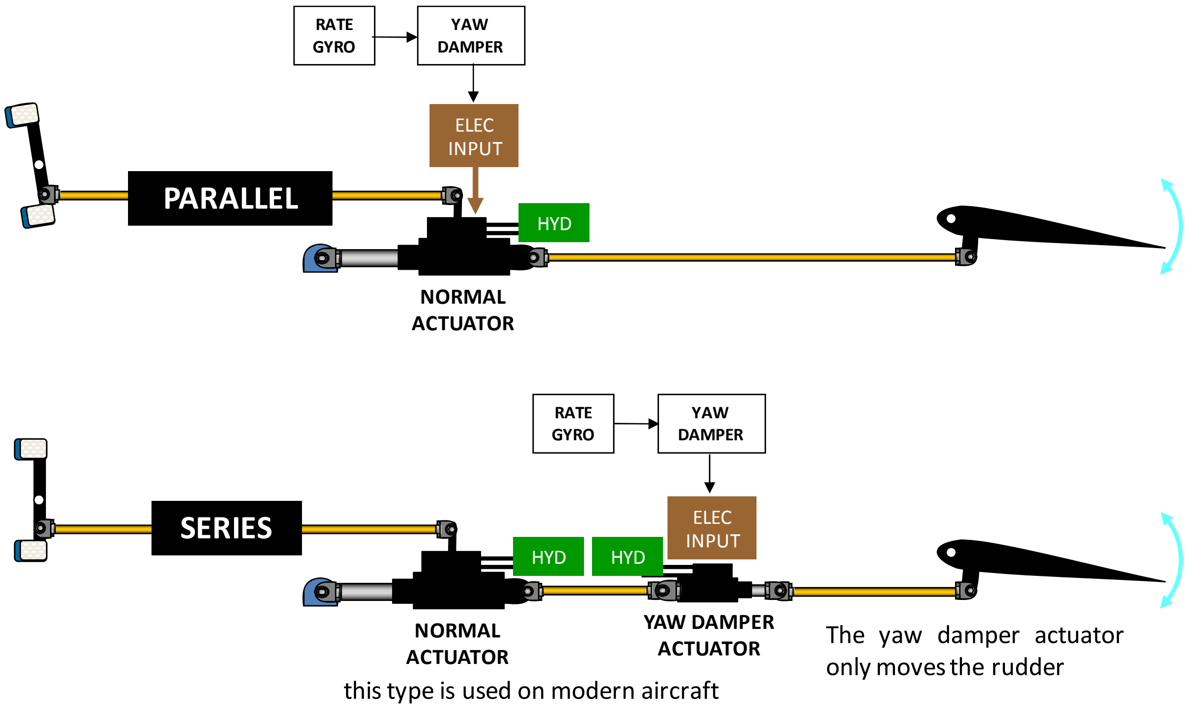


Figure 5-43 Yaw Damper Systems

On modern aircraft the yaw dampers also automatically provide turn co-ordination when conducting turns.

LIFT AUGMENTATION DEVICES

Almost all aircraft are fitted with some form of lift augmentation device providing the capability for a slower landing speed and/or shorter take-off run. Large heavy aircraft with swept wings require multiple forms of lift augmentation to enable them to take-off and land within a sensible runway length at sensible speeds. Additionally, occasions occur when large commercial aircraft are required to maintain holding patterns at lower than normal cruise speeds. The most common methods of providing lift augmentation are;

- trailing edge (T/E) flaps, and
- leading edge (L/E) flaps and/or slats.

On aircraft fitted with both T/E and L/E devices they are operated in conjunction via a single flap control selector. Other not so common methods are used to augment lift and these will be discussed later.

TRAILING EDGE FLAPS

In principle trailing edge flaps will give an increased centre of lift (C_L) with a lower angle of attack (AoA) and give a nose down attitude for a better view out the front for landing. Various types of trailing edge flaps are used depending on the aircraft requirements and may be actuated using hydraulic, electrical or mechanical methods.

On large aircraft T/E flaps are always provided with an alternate operating method as well as automatic protection systems to prevent asymmetric conditions occuring.

Trailing edge flaps on medium to large aircraft are normally extended through a series of five or six positions (depending on the aircraft) to best suit the phase of flight. For example;

- Flap UP – cruise,
- Flap 1° to 5° - manoeuvering,
- Flap 10° to 20° - take-off or approach, and
- Flap 25° to 30° - landing.

Refer to Figure 5-44.

Figure 5-44 Flap Selector showing flap positions

TYPES OF FLAP

Depending on the aircraft type a variety of simple to complex T/E flap configurations are used. Refer to Figure 5-45 and 5-46.

TYPE OF FLAP	INCREASE IN LIFT	CHARACTERISTICS
 PLAIN or CAMBER FLAP	50%	increased camber high drag when fully down nose down pitching moment used on light aircraft
 SPLIT FLAP	60%	increased camber more drag than plain flap nose down pitching moment typical of older aircraft
 SLOTTED FLAP	65%	control of the boundary layer increased camber stalling delayed not so much drag
 FOWLER FLAP	90%	increased camber and wing area best flaps for lift complicated mechanism nose down pitching moment
 DOUBLE or TRIPLE SLOTTED FOWLER FLAP	even more increase in camber and wing area commonly used on most large aircraft high drag when fully down increases the angle of the wing at max lift	

Figure 5-45 Common Flap Types

Figure 5-46 Triple Slotted Fowler Flaps – B747

FLAP PANELS

Depending on the type of flap used the flap panels may be simply hinged at the trailing edge of the wing or in the case of Fowler types mounted on flap tracks allowing extension beyond the wing trailing edge. Additional smaller flap panels are often mechanically connected to the largest flap panel. The method used to extend the flaps is typically by screwjacks rotated by gearboxes within the trailing edge of the wing. Refer to Figure 5-47.

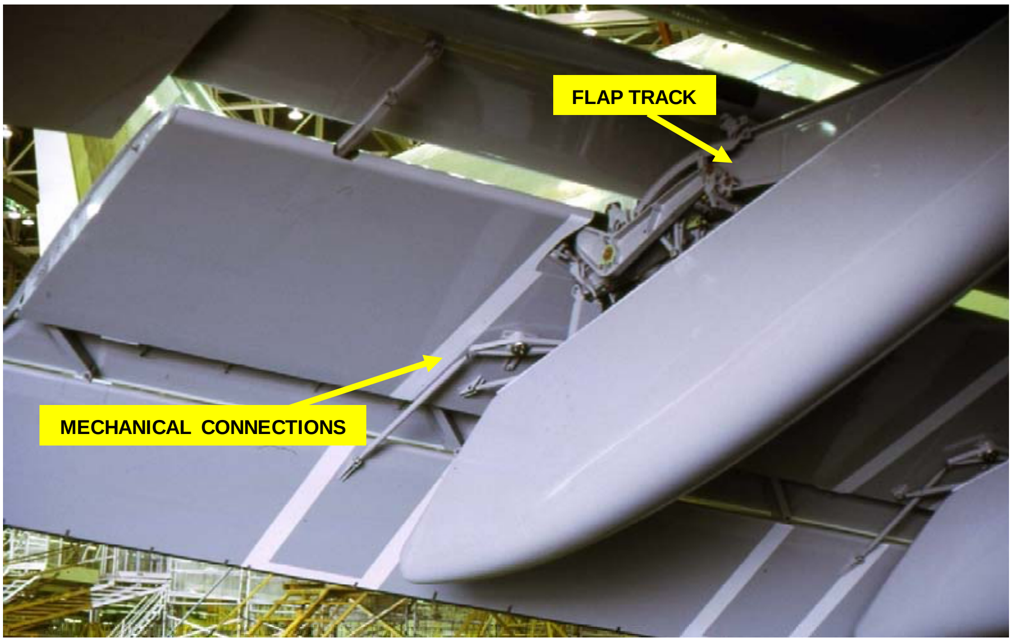


Figure 5-47 Flap Extended

FLAP DRIVES

On light aircraft flaps are typically operated either by mechanical operation by the pilot or electrical actuators controlled by switches in the cockpit.

Large aircraft however almost always use hydraulically driven motors at a fuselage mounted gearbox, rotating torque tubes out to the screwjack gearboxes in each wing. This provides synchronized operation of the flaps on each wing and the capability to include alternate driving methods.

Airbus aircraft favour driving flaps by two separate hydraulic systems simultaneously for normal operation thus allowing for a failure of one system. Boeing aircraft tend to use hydraulics for normal operation and electric motors for the alternate drive method. Refer to Figure 5-45.

FLAP PROTECTION SYSTEMS

Flap systems on large aircraft are automatically protected against uncommanded flap movement and flap asymmetry. If this occurs flaps are locked in position by flap brakes and are unavailable for the remainder of the flight. An alert will be shown in the cockpit for a flap asymmetry and the alternate system is not usable. Flap asymmetry protection must be reset on the ground by maintenance action. Refer to Figure 5-48.

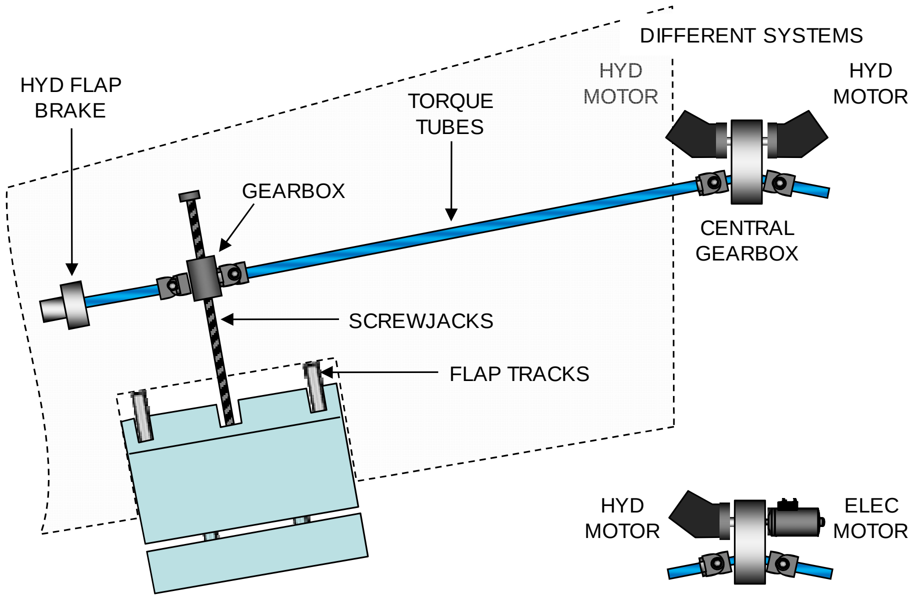


Figure 5-48 Flap Drive Method

Flaps are also protected from excessive loads when extended by the Flap Load Relief Valve discussed previously in Chapter 3, Hydraulic Systems. Recall that if flaps are extended and airspeed increases above the flap position limiting airspeed the flaps will automatically retract back to the next position towards flap up.

LEADING EDGE FLAPS AND SLATS

Aircraft may be fitted with leading edge flaps or slats or a combination of both depending on the requirements of the aircraft. Leading edge slats increase the wing area, camber and allow airflow through a slot to reenergise the boundary layer. Leading edge flaps increase the camber and maintain the boundary layer. Refer to Figure 5.49.

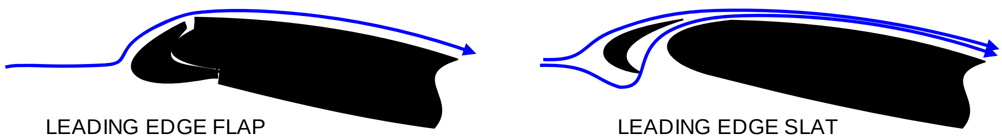


Figure 5-49 Leading Edge Flaps and Slats

For interest on some older types of aircraft leading edge slats could be automatic in that they extended due to their weight when the aerodynamic force was low or sometimes fixed in a permanently extended position for specialist low speed aircraft. Fixed slats are also known as slots.

FLAP AND SLAT PANELS

Flap panels are normally hinged to the leading edge of the wing and are extended by actuators using either hydraulic or in some cases pneumatic power. The most common type are Kreuger flaps used extensively on Boeing aircraft from the wing root to the engine. Refer to Figure 5-50.

Figure 5-50 Kreuger Flap

Slat panels are extended in a similar manner to the trailing edge flaps on tracks. Slat panels are typically anti-iced and therefore need telescopic ducts to carry the bleed air when extended. Refer to Figure 5-51.

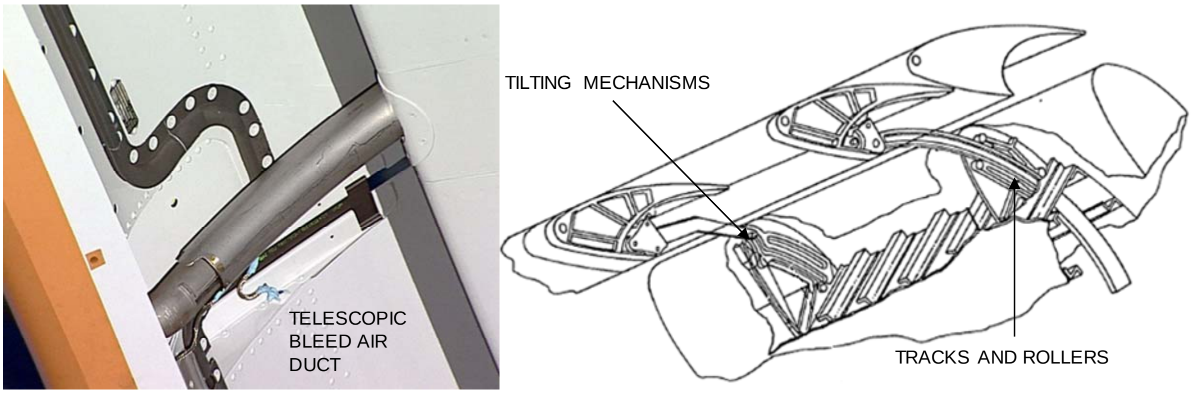


Figure 5-51 Leading Edge Slat

SLAT DRIVES

Slat drives are also operated in a similar manner to the trailing edge flaps using hydraulic or pneumatic motors operating a central gearbox driving torque tubes out through each wing leading edge. The central gearbox us powered in a similar manner by two independent hydraulic motors or a pneumatic motor with an electrical motor for alternate operation.

SLAT PROTECTION SYSTEMS

Slat systems on large modern aircraft are automatically protected against <u>uncommanded slat movement</u> and <u>slat asymmetry</u>. For interest, some aircraft protect their slats from turbulence damage by automatically retracting them when reverse thrust is applied on landing.

LIFT AUGMENTATION CONTROL

Trailing edge flaps and leading edge flaps and/or slats are operated together and follow a specific schedule of configuration depending on the aircraft. The single flap handle in the cockpit controls both. The handle is gated or detented so that the flap handle cannot be accidentally moved to far in one selection. Refer to Figure 5-52.

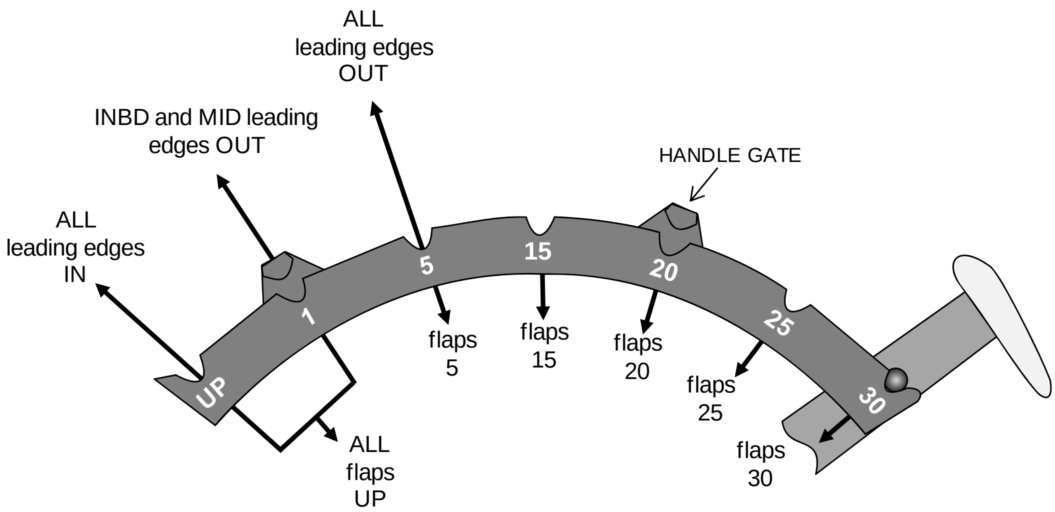
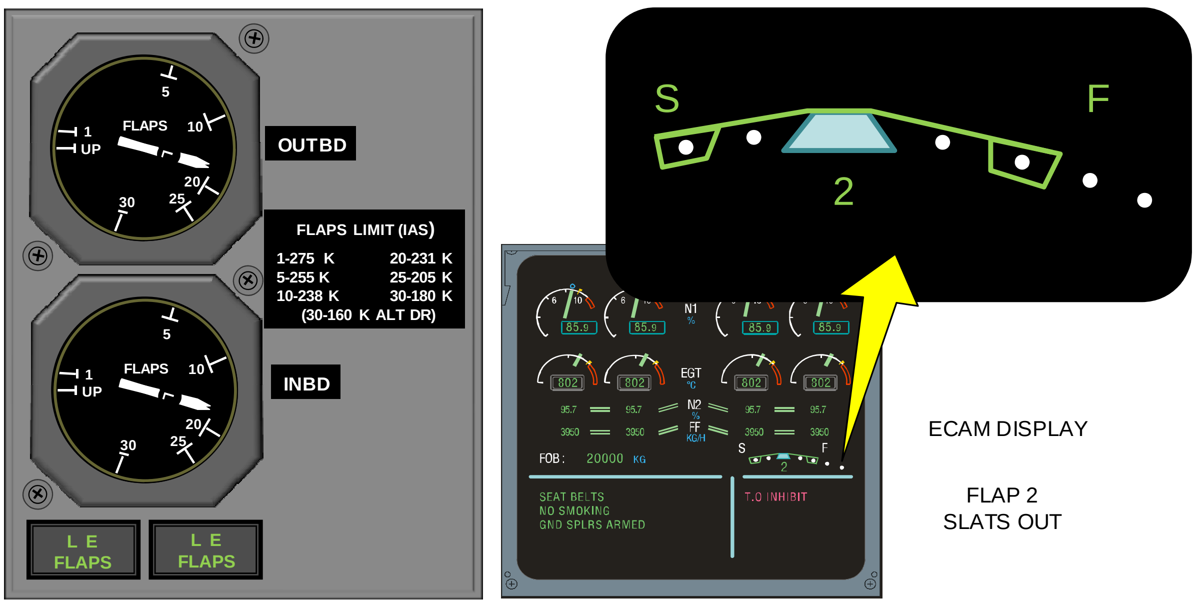


Figure 5-52 Leading Edge and Trailing Edge Schedule

LIFT AUGMENTATION INDICATIONS

All aircraft will have a cockpit indication of the lift augmentation devices as each position is subject to a different airspeed limitation. Shown in Figure 5-53 are examples of traditional and modern methods of display.



TRADITIONAL INDICATION

MODERN INDICATION

Figure 5-53 Leading Edge and Trailing Edge Indications

OTHER LIFT AUGMENTATION DEVICES

There is a variety of other devices in use on different aircraft types to augment lift or control airflow direction. Refer to Figure 5-54 for a summary of other devices in use.

DEVICE NAME	PHOTOGRAPH	REASON FOR USE
CANARDS		Enhances pitch control
WINGLETS		Inhibits wingtip vortex and reduces induced drag
WING FENCES		Inhibit span wise airflow
VORTEX GENERATORS		Reenergises the boundary layer
STRAKES		Influences the airflow to a specific direction
STALL WEDGES		Controls where stall takes place along the leading edge

Figure 5-54 Other Lift Augmentation Devices

OTHER METHODS OF LIFT AUGMENTATION

Some aircraft create extra lift augmentation by the positioning of the engines, thrust vectoring or using bleed air to reenergise the boundary layer. Refer to Figure 5-55 for a summary of methods.

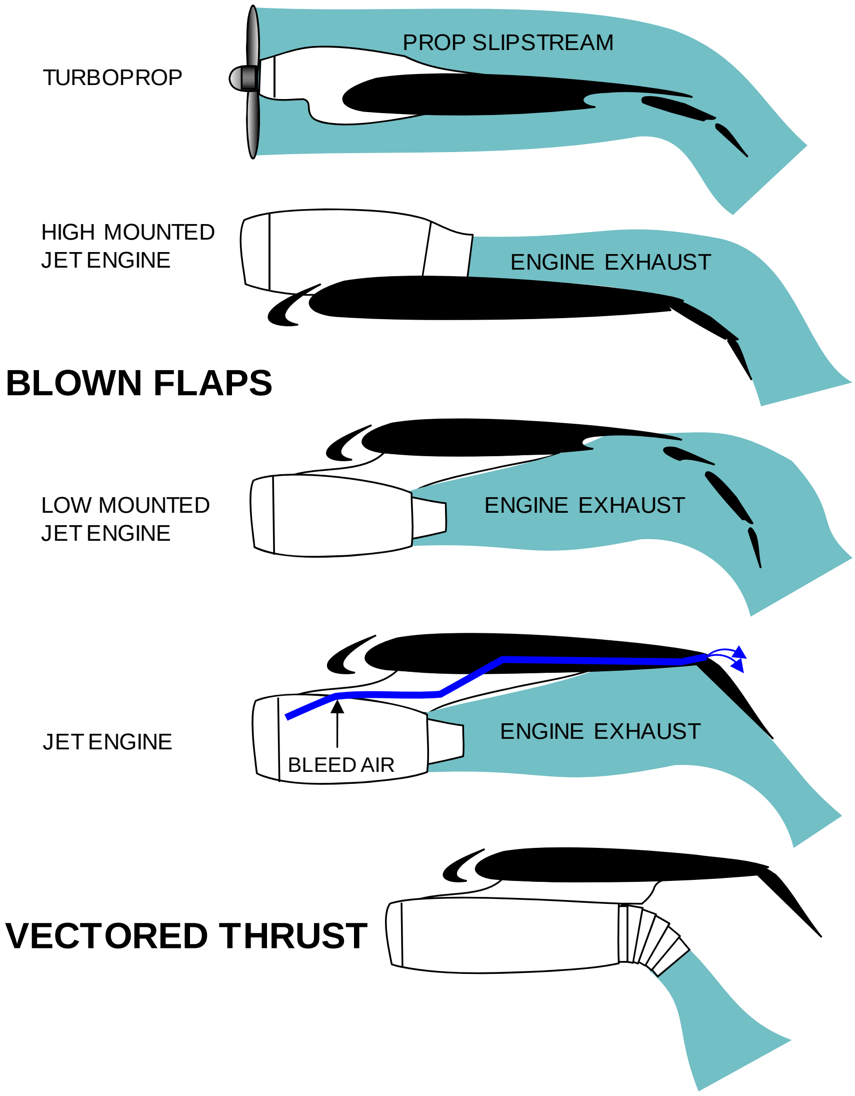


Figure 5-55 Other Methods of Lift Augmentation

FLIGHT CONTROL TERMINOLOGIES AND DEFINITIONS

The following table defines old and/or common terms that you may encounter with reference to flight controls. Refer to Figure 5-56.

TERM REFERRED	DEFINITION
BACKLASH	Free or ineffective movement of the cockpit control when the direction of movement is reversed. A cable operated flight control system should have no backlash.
TENSIONOMETER	A ground equipment device for measuring the tension of a flight control cable.
TURNBUCKLE	A component of a cable run used to adjust the tension of a flight control cable.
LOST MOTION DEVICE	A device fitted at the base of the RH control column only that ensures that all movements are transmitted via the left hand control path irrespective of RH control wheel inputs.
STABILATOR	The name given to a pitch flight control used on small aircraft with unpowered flight controls. The horizontal stabilizer is directly moved by the pilot to act as an elevator. An anti-balance tab provides feel to the pilot.
TAILERON	A term used to describe elevators that also act as ailerons. Acting in the same manner as elevons but mounted on a normal tailplane instead of a delta wing form.
TANDEM ACTUATOR	A single linear flight control actuator that operates using two separate hydraulic systems simultaneously. If one hydraulic system fails the other can still operate the control surface effectively.
CONTROL LIMIT STOPS	Primary flight controls have two sets of mechanical stops to limit the maximum angle that a control surface can be deflected. The PRIMARY STOPS are located at the control surface and are contacted first. The SECONDARY STOPS are located at the cockpit controls.
CONTROL OR GUST LOCKS	Aircraft that have UNPOWERED flight controls require control locks to be fitted when the aircraft is parked. Wind gusts can deflect the control surfaces and cause damage to the flight control system. Control locks are fitted with red streamers to indicate they must be removed before flight.
FAIRED	The term used to describe the position of a control surface or aerofoil structure when it is aligned in the streamlined position relative to its parent structure.
TEMPERATURE COMPENSATOR	A device used in a cable operated flight control system to maintain the cable tension as temperature changes. An aluminium airframe structure will expand to a greater degree than a steel flight control cable.
GEARED TAB	The term geared tab is another name for a balance tab.
BLOW BACK VALVE	Another term for a load relief valve.
DLC	Means Direct Lift Control – Used for approach and landing. When land flap is selected the flight spoilers raise a few degrees to establish a new neutral position. Pitch inputs by the pilot now operate the spoilers causing climb or descent on the glidepath with no change to body angle. Only used on Lockheed Tristar.
DUPLICATE INSPECTIONS	Due to the vital importance of flying controls, if a flight control system is disturbed in any way by maintenance action a duplicate inspection must be carried out separately by two qualified persons. Under certain circumstances the second inspection may be carried out by the Pilot.

Figure 5-56 Flight Control Terms and Definitions

FLIGHT CONTROL QUESTIONS

The following questions will examine your understanding of flight controls. The answers may be found in the text or diagrams of this Handbook.

1. In an aircraft with a flying tail, as the pilot moves the control column;

a. the tailplane moves and the elevator moves in the opposite direction.

b. the tailplane moves and the elevator moves in the same direction.

c. the tailplane moves and the elevator is faired.

2. The aileron lockout system on the flight controls of a large transport jet aircraft operates;

a. at high speeds to lock out the outboard ailerons.

b. at low speeds to lock out the outboard ailerons.

c. at high speeds to lock out the inboard ailerons.

3. Spoilers operate to assist roll control;

a. at low speeds only.

b. at high speeds only.

c. over all normal operating speeds except maximum cruise speed.

4. A fly by wire system of control as used on the latest generation of jet transport aircraft uses;

a. electrical signals and wires in place of linkages and cables to connect the control surface actuators to the flight deck controls.

b. wire cables instead of solid linkages to provide manual reversion capability.

c. a combination of electrical signals and mechanical linkages from the control column to move the control surfaces.

5. The purpose of an internal flexible seal attached to the leading edge of a control surface is to;

a. vary control forces with variations in aircraft speed.

b. transmit feel forces back to the pilot.

c. aerodynamically balance the control by reducing hinge moments.

6. Control Locks are used for;

a. locking the secondary controls when the aircraft is parked.

b. locking the primary controls when the aircraft is parked.

c. locking the flying controls in neutral for control surface rigging.

7. The device used for adjusting flight control cable tension is called a;

a. bellcrank.

b. tensionometer.

c. turnbuckle.

8. Internal balancing of a flight control surface usually means;

a. the control surface has internal weights for balance.

b. a seal is present between the surface and the mainplane.

c. the control surface has a weight inside the “horn”.

9. A control tab that is moved by the main control linkage and causes a deflection in the primary control surface is called a;

a. balance tab.

b. servo tab.

c. trim tab.

10. Manual Reversion is provided;

a. to prevent a runaway trim situation occurring.

b. on aircraft that do not have triple hydraulic redundancy.

c. only on fly by wire type aircraft.

11. When a large jet transport begins a turn to the right at cruise speed the following will occur;

a. on the RH wing, outbd aileron NEUTRAL, inbd aileron UP, flight spoilers fully UP.

b. on the LH wing, outbd aileron NEUTRAL, inbd aileron DOWN, flight spoilers FLUSH.

c. on the LH wing, outbd aileron UP, inbd aileron UP, flight spoilers FLUSH.

12. On large jet transport aircraft the AoA vane is usually located;

a. just before the leading edge wing root on the fuselage.

b. on the leading edge of the mainplane.

c. on the nose area of the aircraft fuselage.

13. In aircraft fitted with a load relief valve when land flap is set and the airspeed increases above the limit airspeed the;

a. trailing edge flaps will automatically retract to the next flap position towards up and provide an alert to the cockpit.

b. leading edge flaps will automatically retract to the next flap position towards up and provide an alert to the cockpit.

c. both leading and trailing edge flaps will automatically retract to the next flap position towards up and provide an alert to the cockpit.

14. During flap retraction an amber flap asymmetry light or alert illuminates. This means that;

a. the ailerons cannot be used for flaperons for landing.

b. inboard or outboard flaps are inoperative.

c. inboard and outboard flaps are inoperative.

15. A device called a stickshaker warns the crew of;

a. low thrust in windshear conditions.

b. approaching the aircraft’s stall speed.

c. a large body angle relative to level.

16. The alternate method of spoiler extension on most aircraft is usually;

a. individual electric motors extending each spoiler panel.

b. mechanical connections from the aileron linkages.

c. none of the above.

17. With the spoiler lever set to the ARMED position prior to landing, ground spoilers will automatically extend when;

a. when all thrust levers are at idle and the weight is on all gears.

b. when all thrust levers are at idle and the weight is on both main gears.

c. when all thrust levers are at idle and the weight is on one main gear.

18. The term ‘q feel’ refers to an artificial feel used in the pitch control channel to adjust the pilots control column feel force relative to;

a. gross weight.

b. airspeed.

c. load factor.

19. In a powered ‘traditional’ flight control system, control centering;

a. is achieved by the override mechanism.

b. is achieved by cable tension.

c. is achieved by opposing springs.

20. An allowable pitch trim setting for take-off is confirmed by;

a. the stabilizer position on preflight walk-around.

b. an illuminated sub section of the trim indicator.

c. the trim position on the flight control position indicator.

21. The term ‘flap gate’ means;

a. a stop point on the flap selector.

b. a lock on the flap lever that must be unlocked prior to selection.

c. another name for the flap load relief system.

22. The term ‘split flap’ relates to;

a. a single flap drive unit that is split between hydraulic and electrical systems.

b. a single flap drive unit that is split between two different hydraulic systems.

c. the failure of one of two separate flap drive units.

23. The term ‘autotrim’ relates to;

a. trimming of the elevators by the autopilot.

b. trimming of the horizontal stabilizer by the autopilot.

c. trimming of the horizontal stabilizer by an automatic servo tab.

24. The term ‘spoiler blowdown’ relates to;

a. aborted landings.

b. increasing airspeed.

c. evacuation of passengers.

25. The term ‘parallel yaw damper’ relates to;

a. a yaw damper system that moves the rudder pedals when operating.

b. a yaw damper system that does not move the rudder pedals when operating.

c. dual yaw damper systems operating in parallel.

26. A yaw damper responds to signals from;

a. a rate gyro.

b. a vertical gyro.

c. the air data computer.