Department of Aeronautical Engineering

II YEAR/IV SEMESTER

AIRCRAFT SYSTEMS AND INSTRUMENTS

COURSE MATERIAL

Faculty

SYLLABUS

AE2252 AIRCRAFT SYSTEMS AND INSTRUMENTS L T P C

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OBJECTIVE

To describe the principle and working of aircraft systems and instruments

UNIT I AIRPLANE CONTROL SYSTEMS 10

Conventional Systems - fully powered flight controls - Power actuated systems – Modern control systems - Digital fly by wire systems - Auto pilot system active control Technology.

UNIT II AIRCRAFT SYSTEMS 12

Hydraulic systems - Study of typical workable system - components - Pneumatic systems - Advantages - Working principles - Typical Air pressure system – Brake system – Typical Pneumatic power system - Components, Landing Gear systems – Classification

UNIT III ENGINE SYSTEMS 8

Fuel systems for Piston and jet engines, - Components of multi engines. Lubricating systems for piston and jet engines, starting and Ignition systems, typical examples for piston and jet engines.

UNIT IV AUXILIARY SYSTEM 8

Basic Air cycle systems - Vapour Cycle systems, Evaporative vapour cycle systems - Evaporative air cycle systems - Fire protection systems, Deicing and anti icing systems.

UNIT V AIRCRAFT INSTRUMENTS 7

Flight Instruments and Navigation Instruments – Gyroscope - Accelerometers, Air speed Indicators – TAS, EAS- Mach Meters - Altimeters - Principles and operation - Study of various types of engine instruments - Tachometers - Temperature gauges - Pressure gauges - Operation and Principles.

TOTAL: 45 PERIODS

1. Mekinley, J.L. and Bent, R.D., “Aircraft Power Plants”, McGraw-Hill, 1993.
2. Pallet, E.H.J., “Aircraft Instruments & Principles”, Pitman & Co., 1993.

UNIT I

AIRPLANE CONTROL SYSTEMS

1. Conventional Control Systems:

1. a. Introduction:

The architecture of the flight control system, essential for all flight operations, has significantly changed throughout the years. Soon after the first flights, articulated surfaces were introduced for basic control, operated by the pilot through a system of cables and pulleys. This technique survived for decades and is now still used for small airplanes.

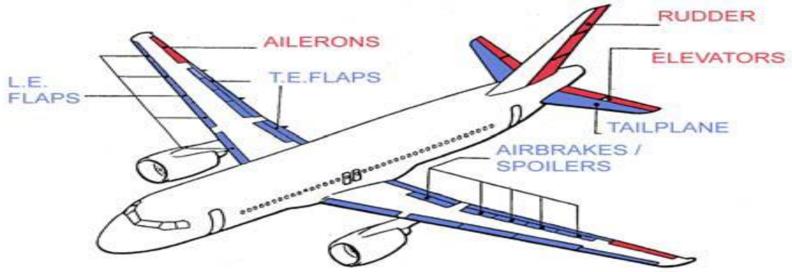
The introduction of larger airplanes and the increase of flight envelopes made the muscular effort of the pilot, in many conditions, not sufficient to contrast the aerodynamic hinge moments consequent to the surface deflection; the first solution to this problem was the introduction of aerodynamic balances and tabs, but further grow of the aircraft sizes and flight envelops brought to the need of powered systems to control the articulated aerodynamic surfaces.

Nowadays two great categories of flight control systems can be found: a full mechanical control on gliders and small general aviation, and a powered, or servo-assisted, control on large or combat aircraft.

One of the great additional effects after the introduction of servomechanisms is the possibility of using active control technology, working directly on the flight control actuators, for a series of benefits:

- compensation for deficiencies in the aerodynamics of the basic airframe;
- stabilization and control of unstable airplanes, that have commonly higher performances;
- flight at high angles of attack;
- automatic stall and spinning protection;
- Gust alleviation.

A further evolution of the servo-assisted control is the fly-by-wire technique, based on signal processing of the pilot's demand before conversion into actuator control. The number and type of aerodynamic surfaces to be controlled changes with aircraft category.



Modern aircraft have often particular configurations, typically as follows:

- elevons on delta wings, for pitch and roll control, if there is no horizontal tail;

- flaperons, or trailing edge flaps-ailerons extended along the entire span:
- tailerons, or stabilizers-ailerons (independently controlled);
- swing wings, with an articulation that allows sweep angle variation;
- Canards, with additional pitch control and stabilization.

Primary flight control capability is essential for safety, and this aspect is dramatically emphasized in the modern unstable (military) airplanes, which could be not controlled without the continued operation of the primary flight control surfaces. For this reason the actuation system in charge of primary control has a high redundancy and reliability, and is capable of operating close to full performance after one or more failures.

Secondary actuation system failure can only introduce flight restriction, like a flapless landing or reduction in the max angle of attack; therefore it is not necessary to ensure full operation after failures.

1.1. Direct mechanical control

As mentioned in the introduction, the linkage from cabin to control surface can be fully mechanical if the aircraft size and its flight envelop allow; in this case the hinge moment generated by the surface deflection is low enough to be easily contrasted by the muscular effort of the pilot.

Two types of mechanical systems are used:

1. Push-pull rods and
2. Cable-pulley.

In the first case a sequence of rods link the control surface to the cabin input. Bell-crank levers are used to change the direction of the rod routings: the fig 1.1 sketches the push-pull control rod system between the elevator and the cabin control column; the bell-crank lever is here necessary to alter the direction of the transmission and to obtain the conventional coupling between stick movement and elevator deflection (column fwd = down deflection of surface and pitch down control).

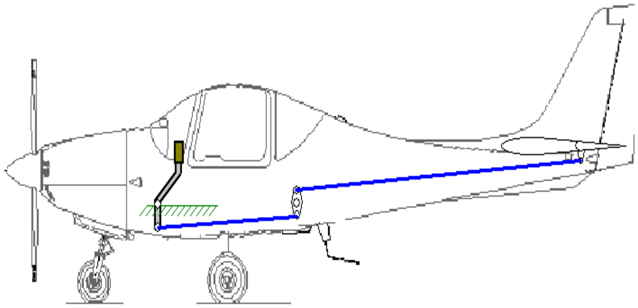


Fig 1.1 (push pull rod system)

From this simplified description the main requirements of a push-pull rod system are clear. First of all the linkage must be stiff, to avoid any unwanted deflection during flight and due to fuselage elasticity. Second, axial instability during compression must be excluded; the instability load P for a rod is given by:

$$\boxed{P = \pi^2 EI/\lambda^2}$$

Where: E = Young modulus; I = cross-section moment of inertia; λ = reference length.

The reference length is linked to the real length of the rod, meaning that to increase the instability load the length must be decreased, or the rods must be frequently constrained by slide guides, or the routing must be interrupted with bell-cranks.

Finally a modal analysis of the system layout is sometimes necessary, because vibrations of the rods can introduce oscillating deflections of the surface; this problem is particularly important on helicopters, because vibrations generated by the main rotor can induce a dramatic resonance of the flight control rods.

The same operation described before can be done by a cable-pulley system, where couples of cables are used in place of the rods. In this case pulleys are used to alter the direction of the lines, equipped with idlers to reduce any slack due to structure elasticity, cable strands relaxation or thermal expansion. Often the cable-pulley solution is preferred, because is more flexible and allows reaching more remote areas of the airplane. An example is sketched in fig. 1.2, where the cabin column is linked via a rod to a quadrant, which the cables are connected to.

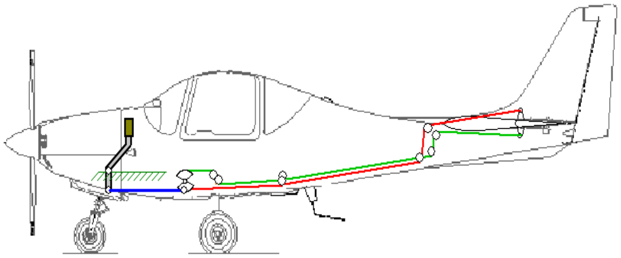


Fig 1.2 (Cable – Pulley system)

1.2. Hydraulic control

When the pilot's action is not directly sufficient for the control, the main option is a powered system that assists the pilot.

A few control surfaces on board are operated by electrical motors: as already discussed in a previous chapter, the hydraulic system has demonstrated to be a more suitable solution for actuation in terms of reliability, safety, weight per unit power and flexibility, with respect to the electrical system, then becoming the common tendency on most modern airplanes: the pilot, via the cabin components, sends a signal, or demand, to a valve that opens ports through which high pressure hydraulic fluid flows and operates one or more actuators.

The valve, that is located near the actuators, can be signaled in two different ways: mechanically or electrically; mechanical signaling is obtained by push-pull rods, or more commonly by cables and pulleys; electrical signaling is a solution of more modern and sophisticated vehicles and will be later on discussed.

The basic principle of the hydraulic control is simple, but two aspects must be noticed when a powered control is introduced:

1. The system must control the surface in a proportional way, i.e. the surface response (deflection) must be function to the pilot's demand (stick deflection, for instance);
2. The pilot that with little effort acts on a control valve must have a feedback on the maneuver intensity

The first problem is solved by using (hydraulic) servo-mechanisms, where the components are linked in such a way to introduce an actuator stroke proportional to the pilot's demand; many examples can be made, two of them are sketched in fig. 1.3, the second one including also the hydraulic circuit necessary for a correct operation. In both cases the control valve housing is solid with the cylinder and the cabin column has a mechanical linkage to drive the valve spool.

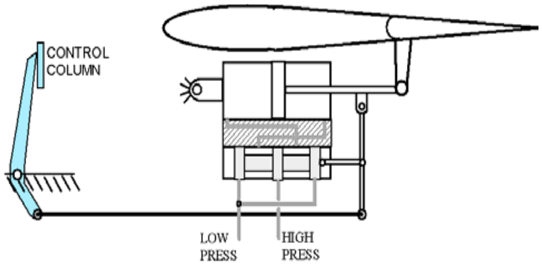


Fig 1.3 (conventional Hydraulic System)

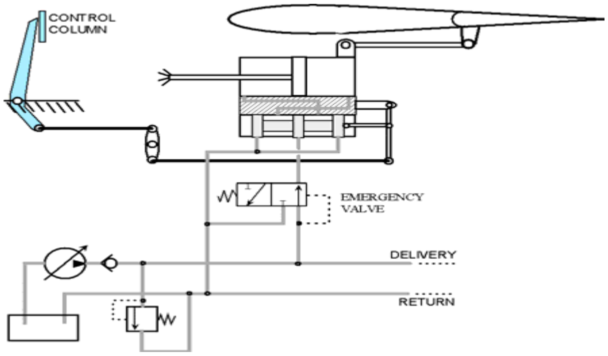


Fig 1.4 (Powered hydraulic control system)

In the first case, the cylinder is hinged to the aircraft and, due to valve spool displacement and ports opening, the piston is moved in one direction or the other; the piston rod is also linked to the valve spool stick, in such a way that the piston movement brings the spool back towards its neutral position; when this is reached, the actuator stops, then obtaining a deflection that is proportional to the demand.

In the second case the piston is constrained to the aircraft; the cabin column controls the valve spool stick; this will result in a movement of the cylinder, and this brings the valve housing again towards the valve neutral position, then resulting in a stroke proportional to the pilot's demand. The hydraulic circuit also includes an emergency valve on the delivery segment to the control valve; if the delivery pressure drops, due for instance to a pump or engine failure, the emergency valve switches to the other position and links all the control valve inlets to the tank; this operation hydraulically unlocks the system, allowing the pilot for manual actuation of the cylinder.

It is clear now that the pilot, in normal hydraulic operating conditions, is requested for a very low effort, necessary to contrast the mechanical frictions of the linkage and the movement of the control valve: the pilot is then no more aware of the load condition being imposed to the aircraft.

For this reason an artificial feel is introduced in powered systems, acting directly on the cabin control stick or pedals. The simplest solution is a spring system, then responding to the pilot's demand with a force proportional to the stick deflection; this solution has of course the limit to be not sensitive to the actual flight conditions. A more sophisticated artificial feel is the so-called Q feel. This system receives data from the pitot-static probes, reading the dynamic pressure, or the difference between total (p_t) and static (p_s) pressure, that is proportional to the aircraft speed v through the air density ρ:

$$\boxed{p_t - p_s = 1/2\,\rho v^2}$$

This signal is used to modulate a hydraulic cylinder that increases the stiffness in the artificial feel system, in such a way that the pilot is given a contrast force in the pedals or stick that is also proportional to the aircraft speed.

1.3. Fully powered Flight Controls:

To actuate the control Surface the pilot has to give full effort. This is very tough to actuate the control surfaces through simple mechanical linkages. One can feel the equal toughness when raising the hand perpendicular to the airflow on riding a motorbike.

In this type of flight control system we will have:

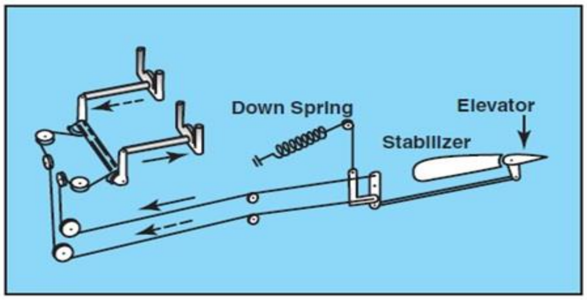


Fig 1.5 (Fully powered flight control)

S.No	Item	Purpose
1	The cable	To transmit the power
2	Cable connector	To connect the cable
3	Turnbuckle	To adjust the Cable length
4	Fairlead	To guide the Cable
5	Pulley	To guide the in radial direction
6	Push pull rod	To go for and aft as per requirement
7	Control stick	To make orders for the remaining circuit

The most basic flight control system designs are mechanical and date back to early aircraft. They operate with a collection of mechanical parts such as rods, cables, pulleys, and sometimes chains to transmit the forces of the flight deck controls to the control surfaces. Mechanical flight control systems are still used today in small general and sport category aircraft where the aerodynamic forces are not excessive. When the pilot pushes the control stick forward/backward the cable is getting tensed through the linkages and it causes the Control surface to move respectively.

2. Modern control systems:

2.1. Digital fly-by-wire systems:

As aviation matured and aircraft designers learned more about aerodynamics, the industry produced larger and faster aircraft. Therefore, the aerodynamic forces acting upon the control surfaces increased exponentially. To make the control force required by pilots manageable, aircraft engineers designed more complex systems. At first, hydro mechanical designs, consisting of a mechanical circuit and a hydraulic circuit, were used to reduce the complexity, weight, and limitations of mechanical flight controls systems.

As aircraft became more sophisticated, the control surfaces were actuated by electric motors, digital computers, or fiber optic cables. Called “fly-by-wire,” this flight control system replaces the physical connection between pilot controls and the flight control surfaces with an electrical interface. In addition, in some large and fast aircraft, controls are boosted by hydraulically or electrically actuated systems. In the fly-by-wire and boosted controls, the feel of the control reaction is fed back to the pilot by simulated means.

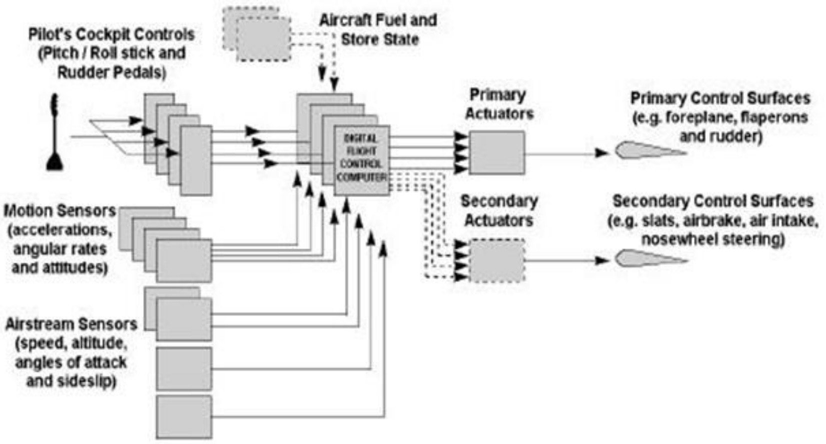


Fig 1.6 (Fly–by–wire system)

Current research at the National Aeronautics and Space Administration (NASA) Dryden Flight Research Center involves Intelligent Flight Control Systems (IFCS). The goal of this flight project is to develop an adaptive neural network-based control system. Applied directly to flight control system feedback errors, IFCS provides adjustments to improve aircraft performance in normal flight as well as with system failures. With IFCS, a pilot is able to maintain control and safely land an aircraft that has suffered a failure to a control surface or damage to the airframe. It also improves mission capability, increases the reliability and safety of flight, and eases the pilot workload.

Direct mechanical linkages were used between the pilot's cockpit controls (pitch/roll stick and rudder pedals) and the control surfaces that maneuver the aircraft, which are for this example: tail plane, ailerons and rudder. This arrangement is inherently of high integrity, in terms of probability of loss of aircraft control, and provides us with a very visible baseline for explaining FCS developments.

The main emphasis is now on digital computing with the use of inertial motion and air stream sensor units; the direct mechanical linkages between the cockpit controls and the control surfaces have been removed and replaced with electrical signaling with direct motion commands, hence the term 'fly-by-wire'. This arrangement provides a significant reduction in mechanical complexity. In order to achieve the same level of integrity as that achieved with the earlier mechanical systems, multiple signal sources and several lanes of computing are necessary to provide redundancy, these being cross-monitored in order to isolate any failed equipment and to ensure safe operation.

A comprehensive built-in-test capability is also included, to ensure that the system is 'safe to fly' prior to each flight and to identify and locate failures.

2.1.1 *The Benefits of Fly-by-wire Technology:*

The major benefit of fly-by-wire is the ability to tailor the system's characteristics at each point in the aircraft's flight envelope. This is achieved by using 'control laws', which can be scheduled with flight condition. The introduction of digital computing for aircraft flight control has allowed complex algorithms to be implemented. These functions allow the performance benefits offered by Active Control Technology to be fully realized and include:

- ✓ 'Carefree Handling' by:
    1. providing angle of attack control and angle of sideslip suppression, which lead to automatic protection against stall and departure;
    2. By the automatic limiting of normal acceleration and roll rate to avoid over-stressing of the airframe.
- ✓ Handling qualities optimized across the flight envelope, and for a wide range of aircraft stores.
- ✓ Aircraft agility, thereby providing a capability for rapid changes in fuselage aiming and / or velocity vector, to enhance both target capture and evasive maneuvering.
- ✓ Aircraft performance benefits associated with controlling an unstable airframe, that is, improved lift / drag ratio and an increase in maximum lift capability, both leading to increased aircraft turning capability.
- ✓ The use of thrust vectoring to augment or replace aerodynamic control powers, in order to extend an aircraft's conventional flight envelope.
- ✓ Reduced drag due to optimized trim setting of controls, including thrust vectoring.
- ✓ Reduced maintenance costs, resulting from the reduction in mechanical complexity and the introduction of built-in-test.
- ✓ In order to realize these benefits it is essential to establish appropriate control law architecture. This is fundamental to the success of the system and will require good knowledge of systems equipment engineering and safety, flight dynamics and flight control. There is however, a significant cost associated with such performance benefits, in terms of system complexity, but usually, the performance and safety benefits that can be achieved, easily justify the necessary investment.

2.2 Auto pilot System

An autopilot is a mechanical, electrical, or hydraulic system used to guide a vehicle without assistance from a human being. An autopilot can refer specifically to aircraft, self-steering gear for boats, or auto guidance of space craft and missiles.

Today, autopilots are sophisticated systems that perform the same duties as a highly trained pilot. In fact, for some in-flight routines and procedures, autopilots are even better than a pair of human hands. They don't just make flights smoother -they make them safer and more efficient.

2.2.1 Autopilots and Avionics

In the world of aircraft, the autopilot is more accurately described as the automatic flight control system (AFCS). An AFCS is part of an aircraft's avionics – the electronic systems, equipment and devices used to control key systems of the plane and its flight. In addition to flight control systems, avionics include electronics for communications, navigation, collision avoidance and weather. The original use of an AFCS was to provide pilot relief during tedious stages of flight, such as high-altitude cruising. Advanced autopilots can do much more, carrying out even highly precise maneuvers, such as landing an aircraft in conditions of zero visibility.

Although there is great diversity in autopilot systems, most can be classified according to the number of parts, or surfaces, they control. To understand this discussion, it helps to be familiar with the three basic control surfaces that affect an airplane's attitude.
Autopilots can control any or all of these surfaces. A single-axis autopilot manages just one set of controls, usually the ailerons. This simple type of autopilot is known as a "wing leveler" because, by controlling roll, it keeps the aircraft wings on an even keel.
A two-axis autopilot manages elevators and ailerons. Finally, a three-axis autopilot manages all three basic control systems: ailerons, elevators and rudder.

2.2.2 Autopilot Parts

The heart of a modern automatic flight control system is a computer with several high-speed processors. To gather the intelligence required to control the plane, the processors communicate with sensors located on the major control surfaces. They can also collect data from other airplane systems and equipment, including gyroscopes, accelerometers, altimeters, compasses and airspeed indicators.

The processors in the AFCS then take the input data and, using complex calculations, compare it to a set of control modes. A control mode is a setting entered by the pilot that defines a specific detail of the flight. For example, there is a control mode that defines how an aircraft's altitude will be maintained. There are also control modes that maintain airspeed, heading and flight path.

These calculations determine if the plane is obeying the commands set up in the control modes. The processors then send signals to various servomechanism units. A servomechanism, or servo for short, is a device that provides mechanical control at a distance. One servo exists for each control surface included in the autopilot system. The servos take the computer's instructions and use motors or hydraulics to move the craft's control surfaces, making sure the plane maintains its proper course and attitude.

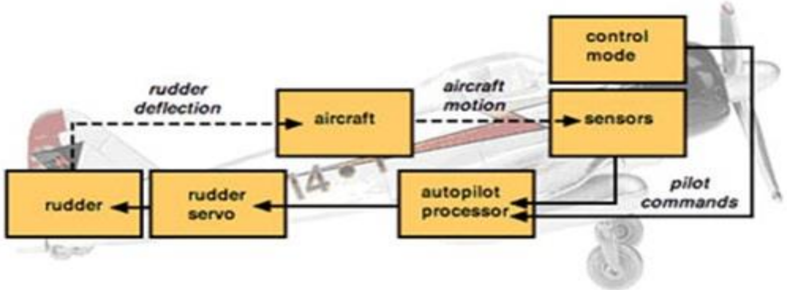


Fig 1.7 (Auto pilot system)

The above illustration shows how the basic elements of an autopilot system are related. For simplicity, only one control surface -- the rudder -- is shown, although each control surface would have a similar arrangement. Notice that the basic schematic of an autopilot looks like a loop, with sensors sending data to the autopilot computer, which processes the information and transmits signals to the servo, which moves the control surface, which changes the attitude of the plane, which creates a new data set in the sensors, which starts the whole process again. This type of feedback loop is central to the operation of autopilot systems.

2.2.3 Autopilot Control Systems

An autopilot is an example of a control system. Control systems apply an action based on a measurement and almost always have an impact on the value they are measuring. A classic example of a control system is the negative feedback loop that controls the thermostat in your home. Such a loop works like this:

1. Its summertime and a homeowner set his thermostat to a desired room temperature say 78°F.
2. The thermostat measures the air temperature and compares it to the preset value.
3. Over time, the hot air outside the house will elevate the temperature inside the house. When the temperature inside exceeds 78°F, the thermostat sends a signal to the air conditioning unit.
4. The air conditioning unit clicks on and cools the room.
5. When the temperature in the room returns to 78°F, another signal is sent to the air conditioner, which shuts off.

It's called a negative feedback loop because the result of a certain action (the air conditioning unit clicking on) inhibits further performance of that action. All negative feedback loops require a receptor, a control center and an effecter. In the example above, the receptor is the thermometer that measures air temperature. The control center is the processor inside the thermostat. And the effecter is the air conditioning unit.

Automated flight control systems work the same way. Let's consider the example of a pilot who has activated a single-axis autopilot -- the so-called wing leveler we mentioned earlier.

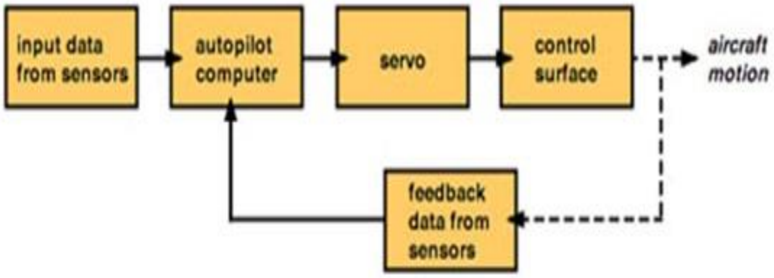


Fig 1.8 (single axis auto pilot)

1. The pilot sets a control mode to maintain the wings in a level position.
2. However, even in the smoothest air, a wing will eventually dip.
3. Position sensors on the wing detect this deflection and send a signal to the autopilot computer.
4. The autopilot computer processes the input data and determines that the wings are no longer level.
5. The autopilot computer sends a signal to the servos that control the aircraft's ailerons. The signal is a very specific command telling the servo to make a precise adjustment.

   a) Each servo has a small electric motor fitted with a slip clutch that, through a bridle cable, grips the aileron cable. When the cable moves, the control surfaces move accordingly.
   b) As the ailerons are adjusted based on the input data, the wings move back toward level.

c) The autopilot computer removes the command when the position sensor on the wing detects that the wings are once again level.
d) The servos cease to apply pressure on the aileron cables.

This loop, shown above in the block diagram, works continuously, many times a second, much more quickly and smoothly than a human pilot could. Two- and three-axis autopilots obey the same principles, employing multiple processors that control multiple surfaces. Some airplanes even have auto thrust computers to control engine thrust. Autopilot and auto thrust systems can work together to perform very complex maneuvers.

Autopilot Failure

Autopilots can and do fail. A common problem is some kind of servo failure, either because of a bad motor or a bad connection. A position sensor can also fail, resulting in a loss of input data to the autopilot computer. Fortunately, autopilots for manned aircraft are designed as a failsafe -- that is, no failure in the automatic pilot can prevent effective employment of manual override. To override the autopilot, a crew member simply has to disengage the system, either by flipping a power switch or, if that doesn't work, by pulling the autopilot circuit breaker.

Some airplane crashes have been blamed on situations where pilots have failed to disengage the automatic flight control system. The pilots end up fighting the settings that the autopilot is administering; unable to figure out why the plane won't do what they're asking it to do. This is why flight instruction programs stress practicing for just such a scenario. Pilots must know how to use every feature of an AFCS, but they must also know how to turn it off and fly without it. They also have to adhere to a rigorous maintenance schedule to make sure all sensors and servos are in good working order. Any adjustments or fixes in key systems may require that the autopilot be tweaked. For example, a change made to gyro instruments will require realignment of the settings in the autopilot's computer.

Modern Autopilot Systems

Many modern autopilots can receive data from a Global Positioning System (GPS) receiver installed on the aircraft.

A GPS receiver can determine airplane's position in space by calculating its distance from three or more satellites in the GPS network. Armed with such positioning information, an autopilot can do more than keep a plane straight and level -- it can execute a flight plan.

Most commercial jets have had such capabilities for a while, but even smaller planes are incorporating sophisticated autopilot systems.

UNIT II

AIRCRAFT SYSTEMS

2.1 Hydraulic Systems:

The word hydraulics is based on the Greek word for water, and originally meant the study of water at rest and in motion. Today the meaning has been expanded to include the physical behavior of all liquids, including hydraulic fluid. With the use of incompressible phenomenon of liquid we can easily make a hydraulic system.

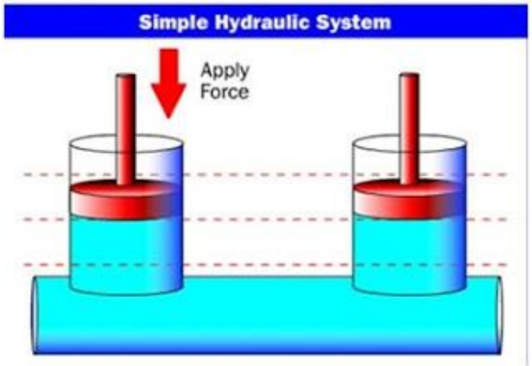


Fig 2.1 (Typical hydraulic system)

As per Pascal's law "Pressure applied to any part of a confined liquid is transmitted with undiminished intensity to every other parts" .The basic idea behind any hydraulic system is very simple: **Force that is applied at one point is transmitted to another point using an incompressible fluid.** The fluid is almost always an oil of some sort. The force is almost always multiplied in the process.

In this drawing, two pistons (red) fit into two glass cylinders filled with oil (light blue) and connected to one another with an oil-filled pipe. If you apply a downward force to one piston (the left one in this drawing), then the force is transmitted to the second piston through the oil in the pipe. Since oil is in-compressible, the efficiency is very good -- almost all of the applied force appears at the second piston. The great thing about hydraulic systems is that the pipe connecting the two cylinders can be any length and shape, allowing it to snake through all sorts of things separating the two pistons. The pipe can also fork, so that one **master cylinder** can drive more than one **slave** cylinder if desired.

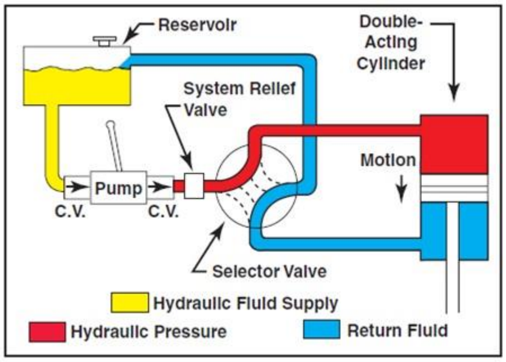


Fig 2.2 (Typical workable system)

There are multiple applications for hydraulic use in airplanes, depending on the complexity of the airplane. For example, hydraulics is often used on small airplanes to operate wheel brakes, retractable landing gear, and some constant speed propellers. On large airplanes, hydraulics is used for flight control surfaces, wing flaps, spoilers, and other systems.

Components of a Hydraulic System:

A basic hydraulic system consists of a reservoir, pump (either hand, electric, or engine driven), a filter to keep the fluid clean, selector valve to control the direction of flow, relief valve to relieve excess pressure, and an actuator. The hydraulic fluid is pumped through the system to an actuator or servo.

***Types of Hydraulic Fluids*:**

When adding fluid to the system, use the specified type of fluid in the manufactures manual. There are 3 types of fluids are currently being used in civil aircraft

Vegetable base hydraulic fluid
Mineral base hydraulic fluid
Phosphate ester base hydraulic fluid

Advantages:

1. Ease of installation
2. Simple inspection needed & requires minimum maintenance

Air in the System:

It is important that a hydraulic system contains no air bubbles. You may have heard about the need to "bleed the air out of the brake lines" of your car. If there is an air bubble in the system, then the force applied to the first piston gets used compressing the air in the bubble rather than moving the second piston, which has a big effect on the efficiency of the system.

Control Surface deflection using hydraulic system

- The piston rod can only produce Reciprocating motion.
- Reciprocating motion can be converted to Radial or oblique motion by the use of mechanical linkages.

2.2 Pneumatic systems:

Pneumatic is a branch of technology, which deals with the study and application of pressurized gas to effect mechanical motion.

Pneumatic systems are extensively used in industry, where factories are commonly plumbed with compressed air or compressed inert gases. This is because a centrally located and electrically powered compressor that powers cylinders and other pneumatic devices through solenoid valves is often able to provide motive power in a cheaper, safer, more flexible, and more reliable way than a large number of electric motors and actuators.

Pneumatic also has applications in dentistry, construction, mining, and other areas.

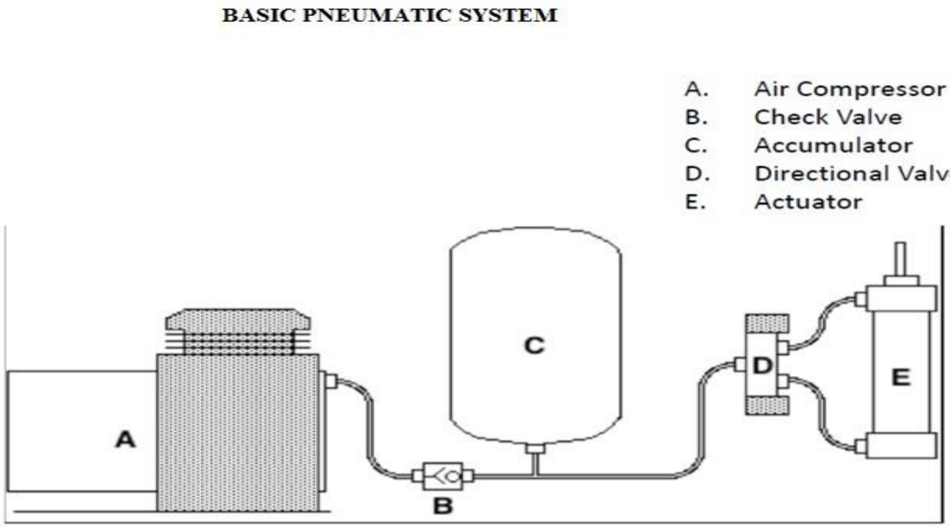


Fig 2.3 (Schematic diagram of a pneumatic system)

Components in a Pneumatic System:

Compressor:

Pump that compresses air, raising air pressure to above ambient pressure for use in pneumatic systems.

Check valve:

One-way valve - allows pressurized air to enter the pneumatic system, but prevents backflow of air toward the Compressor when Compressor is stopped (prevent loss of pressure.

Accumulator:

- Stores compressed air,
- Prevents surges in pressure
- Prevents constant Compressor operation (“duty cycles” of Compressor)

Directional Valve: (Selector valve)

- Controls pressurized air flow from Accumulator (source to user equipment via selected port
- Some valves are one way – shut tight
- Some valves are two way, allowing free exhaust from the port not selected
- Valves can be actuated manually or electrically.

Actuator:

- Converts energy stored in compressed air into mechanical motion
- Example is a linear piston (piston limited to moving in two opposing directions)
- Other examples are alternate tools including: rotary actuators, air tools, expanding bladders, etc

Pneumatic uses in Aircraft:

- Powers engine Suction System for Heading indicators and Attitude indicators.
- Actuates Landing Gear (some aircraft)
- Emergency Brakes (some aircraft)
- Cabin Pressure (for pressurized aircraft)

Advantages:

- Light weight
- Safe
- Reliable
- Unaffected by atmospheric changes
- Inexpensive components
- Seals are problem free
- Force transmission is easy to handle

2.3 Pneumatic power generation and control:

The turbine engine is a generator of high-speed gas aimed to provide thrust for the aircraft. Before entering the combustion chamber and being mixed with atomized fuel, the external air is processed by a multi-stage axial compressor, driven by the turbine.

From one or more stages of the compressor, a limited volume of air can be bled without significant degradation of the engine performances. Then the engine compressor is responsible for the pneumatic power generation on board.

Two remarks are relevant for this kind of compressed air generation:

1. The system needs a regulation; because bled air conditions depend on engine functioning conditions and these vary from idle (low pressure and temperature) to max thrust (high pressure and temperature)

2. In some flight conditions a reduced amount of air can be bled from the compressor to avoid significant breakdown in engine performance, especially when max thrust is requested.

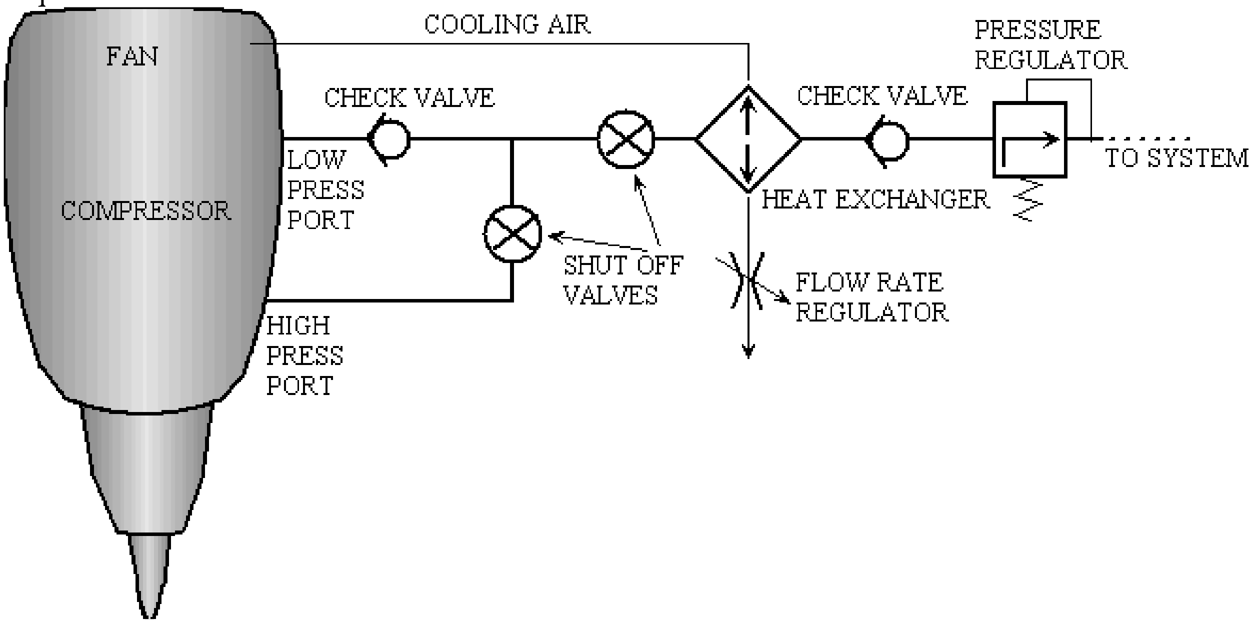


Fig 2.4 (Pneumatic power generation system)

The sketch in fig. 2.4 summarizes the components of pneumatic system generation for a turbofan engine. Air is commonly bled at two different stages of the compressor: a low pressure port at an intermediate stage (around 7TH stage) and a high pressure port at a final stage (around 15TH stage). A check valve is necessary to prevent air flowing from high to low pressure bleeding ports. The low pressure bleeding port is normally open, but can be excluded with the shut-off valve if the engine is in critical conditions; the high pressure port is open when the pressure coming from the intermediate stage is not adequate, or a considerable amount of air is necessary, and anyway the engine must be in operating conditions that cannot be deteriorated by intensive air bleeding: typically this bleeding is operated during taxiing or descent, with the engine near idle.

A low flow rate can be extracted from the engine between 2 and 8 % of the total flow rate processed, but a significant amount of energy content. The same amount of energy is obtained by compressed air extracted from the APU, but the bleeding rate is here around 70-80% of the total flow rate, because the APU is not finalized to generate thrust with the exhaust gases. This allows operation of all pneumatic uses when the aircraft is on ground with engines in particular the environmental control system and engine starting.

Bleed air conditions from the compressor stages range, for a modern turbofan, from 0.2 to more than 1 MPa in pressure and from 180 to more than 350 °C in temperature, depending on altitude and engine speed. Because the generated air is at a temperature higher than that requested by the uses, and may be too hot to be canalized safely to other regions of the aircraft, it is cooled through a heat exchanger with fresh external air before going to the pneumatic system delivery (see again fig. 2.4). By metering the fresh cooling air with a flow rate regulator, the compressed air temperature is controlled, usually for a final temperature around 175 °C. Moreover a regulator on the compressed air line keeps the pressure to system at about 0.3 MPa.

2.4 Landing Gear:

Landing gear is that portion of an aircraft consisting of the wheels, tires, brakes, energy absorption mechanism, and drag brace. The landing gear is also referred to as the aircraft undercarriage. Additional components attached to and functioning with the landing gear may include retracting mechanisms, steering devices, shimmy dampers, and door panels.

The landing gear supports the aircraft on the ground and provides a means of moving it. It also serves as the primary means of absorbing the large amounts of energy developed in the transition from flight to ground roll during a landing approach. The brakes, normally located in the main wheels, are used to retard the forward motion of the aircraft on the ground and may provide some control in the steering of the aircraft. In most modern aircraft the landing gear is designed to retract into the aircraft so that it is out of the air-stream and drag is thus reduced.

Early aircraft and many small aircraft use a tail-wheel (or skid) in a conventional, or tail-dragger arrangement, in which the main landing gear is located ahead or forward of the center of gravity of the aircraft. The popular arrangement on modern aircraft is a tricycle landing gear, with the main gear located behind or aft of the center of gravity, and a nose gear located forward which carries about 20% of the static weight of the aircraft. Large aircraft such as the wide-body commercial aircraft and military aircraft like the C-5 A, employ multiple-wheeled bogies to support their huge weight and to provide soft terrain landing and takeoff capability.

The most accepted method of absorbing the energy due to landing is an air-oil strut called an oleo. The basic components are an outer cylinder which contains the air-oil mixture and an inner piston that compresses the oil through an orifice. The flow of oil through the orifice is metered by a variable-diameter pin that passes through the orifice as the gear strokes. The flow of oil in effect varies the stiffness of the compression of the gear.

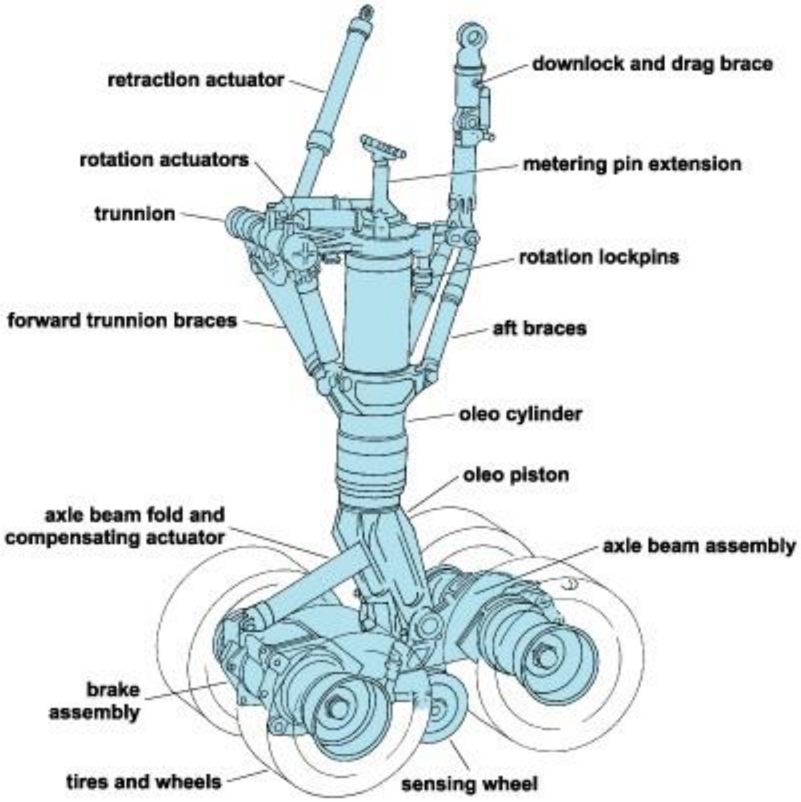


Fig 2.5 (Landing Gear systems)

2.4.1 Landing Gear Configurations

Two main types:

- Conventional,
- Tricycle

Tricycle

- Has nose wheel, which may be steerable
- Main gear, on either side
- Example: Cessna
- Keeps aircraft level during take-off and landing
- The most important advantage is its ease of ground handling.

Conventional

- Two main wheels
- One tail dragger wheel
- Reduced drag in the air
- Reduced landing gear weight
- Requires more skill in ground taxiing
- The most important advantage is the ability to operate the aircraft over rough terrain.

2.4.1.1 Classification of Landing Gear

Main landing gear

- Cushions landing impact
- Heavily stressed area
- Main Landing Gear consists of the main weight-bearing structure
- Auxiliary landing gear includes tail wheels, skids, nose wheels, etc.

Non-absorbing Landing Gear

- Includes Rigid landing gear, Shock-cord landing gear, Spring landing gear
- Rigid: helicopters, sailplanes. No flexing other than the structure.
- Shock cord system: uses "Bungee" cords
- Spring type uses spring steel (some Cessna's)

Shock-Absorbing Landing Gear

- Dissipates landing energies by forcing fluid through a restriction
- This fluid generates heat, dissipated into the atmosphere
- Two types: Spring Oleo, and Air-Oil Oleo
- Spring Oleo is history by now
- Air Oleos are all very similar: a needle valve restricts fluid flow
- Air in the oleo holds the weight of the a/c on the ground
- Air Oleos present in both retractable and fixed gears

Fixed Gear

- Non retractable, usually bolted on to the structure
- Often uses fairings or wheel pants
- Cessna 152
- Advantages:
  - ➢ Lighter weight
  - ➢ Less complex
  - ➢ Least costly

Retractable Gear

- Designed to eliminate drag (the greatest advantage)
- Can be either fully or partially retractable
- Direction of retraction depends on airframe model
- Methods of retraction: hydraulic, electric, mechanical, pneumatic
- Critical area of aircraft maintenance for safety reason

Hulls and Floats

- Can be single float, or multiple
- Definition may include floating hulls (ex. "Lake" aircraft)
  - ▪ Floating hulls may only require wing tip floats
- Skis used for snow and ice (wood, metal, composites)
  - ▪ Skis may use shock cord to assist angle of ski attack
  - ▪ Skis are mounted on the same strut as tires

2.4.1.2 Landing Gear Components

- Exact definitions of some components will vary
- The Oleo strut is the widely used form of shock absorption on aircraft landing gear.

Trunnions

- Portion of the landing which attaches to the airframe
- Supported at the ends by bearings
- Landing gear traditionally extends from the center

Struts

- Vertical member, contains the shock absorbing mechanism
- Top of the strut mounts onto the trunnion
- Strut forms the cylinder for the oleo ("outer" cylinder)
- Piston is the moving portion (aka piston rod, tube or inner cylinder)
- Oil is forced from the lower portion of the strut to the upper
- Oil flow is restricted or varied according to a metering pin
- Final weight of a/c rests on air in the top of the strut
- Snubbers are used to prevent a sudden dropping of gear on takeoff
- Metering pin controls the flow of fluid between the chambers.
- The shock of landing is absorbed by the fluid being forced through a metered orifice. The metering pin gradually reduces the size of the orifice as the shock strut extends, which avoids a rapid extension after the initial shock of landing and related bounce.
- Chevron seals are used in shock struts to prevent the oil from escaping
- On nose wheel struts, a cam is built into the strut for the purpose of straightening the nose wheel before retraction.
- Filling a shock strut: "exercise" the strut in order to seat the seals, and remove air bubbles from the fluid.
- Most shock strut oil levels are checked by releasing the air, bottoming the strut, and checking to see if the oil is at the level of the filler plug.
- Information about shock struts: see:
    - Manufacturer's maintenance manual
    - Information decal located on the strut
    - Mfr's overhaul manual

Torque Links

- Also called scissors assembly
- Two A-frame members
- Connects and aligns upper and lower cylinders
- Connects the strut cylinder to the piston
- Restricts extension of piston during retraction
- Correctly aligns axle to the strut

Trucks

- Located at the bottom of the strut piston
- Axles are mounted on the truck
- Trucks can tilt fore or aft to allow for a/c attitude changes

Drag Links

- Stabilizes landing gear longitudinally

- May be hinged to allow retraction
- Also called a drag strut

Side Brace Links

- Stabilize gear laterally
- May be hinged to allow retraction
- Can be called a side strut

Over center Links (aka down lock mechanism)

- Use to apply pressure to the center pivot joint in a drag or side brace link
- Over center link is hydraulically retracted to allow gear retraction
- Also called a down lock, and/or a jury strut

Swivel Glands

- Flexible joint with internal passages
- Route hydraulic fluid to the wheel brakes
- Used where space limitation eliminate flex hoses

Shimmy Dampers

- Hydraulic snubbing unit
- Reduces tendency of nose wheels to oscillate

Piston type dampers

- Piston and rod filled with hydraulic fluid
- Piston has an orifice restricting speed of travel
- Slow movement has no restriction
- Large shimmy dampers incorporate temperature compensation

Vane type dampers

- Employ stationary vanes and rotating vanes
- Small passages restrict fluid movement
- Central shaft rotation is restricted from moving quickly

Damper Inspections

- Check for leakage & effectiveness of operation
- Check mounting bolts and hardware
- Most dampers are fairly reliable