MODULE V

DESIGN ASPECTS OF SUBSYSTEMS

Prepared by
Dr. Deepa M S
Professor
Department of Aeronautical Engineering
SJCIT

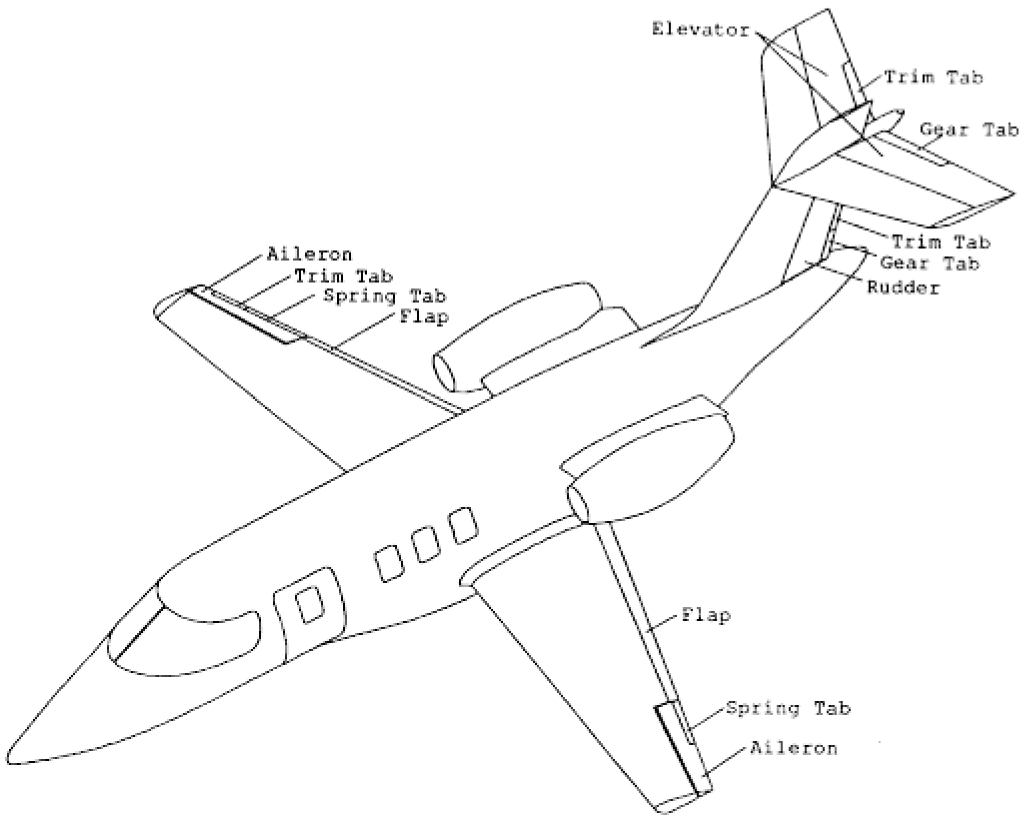
5.1 FLIGHT CONTROL SYSTEMS:

Flight Control System (FCS) Control system consists of 4 basic elements: • Pilot/ autopilot

• Linkage

• Actuators

• Control system



Conventional trailing edge flying control surfaces are divided into:

– Primary group

• Aileron

• Elevator

• Rudder

– Secondary group

• Trim tab

• Spring tab

– Auxiliary group

• Wing flaps

• Spoilers

• Speed breakers

• Slat

- All moving tail plane and fore planes
- Reaction devices
- Linkage between pilot and control surface
  - Relaxed static stability
  - Maneuver load control
  - Gust load alleviation

5.2 LANDING GEAR ARRANGEMENTS

The common options for landing-gear arrangement are shown. The single main gear is used for many sailplanes because of its simplicity. The wheel can be forward of the center of gravity (e.g.), as shown here, or can be aft of the c.g. with a skid under the cockpit.

"Bicycle" gear has two main wheels, fore and aft of the e.g.: with stall "outrigger" wheels. The bicycle landing gear has the aft wheel that the aircraft must take off and land in a flat attitude, which limits this type of gear to aircraft with high lift at low angles of attack (i.e., high-aspect-ratio Wings with large camber and/or flaps. Bicycle gear has been used mainly on aircraft with narrow fuselage and wide wing span such as the B-47.

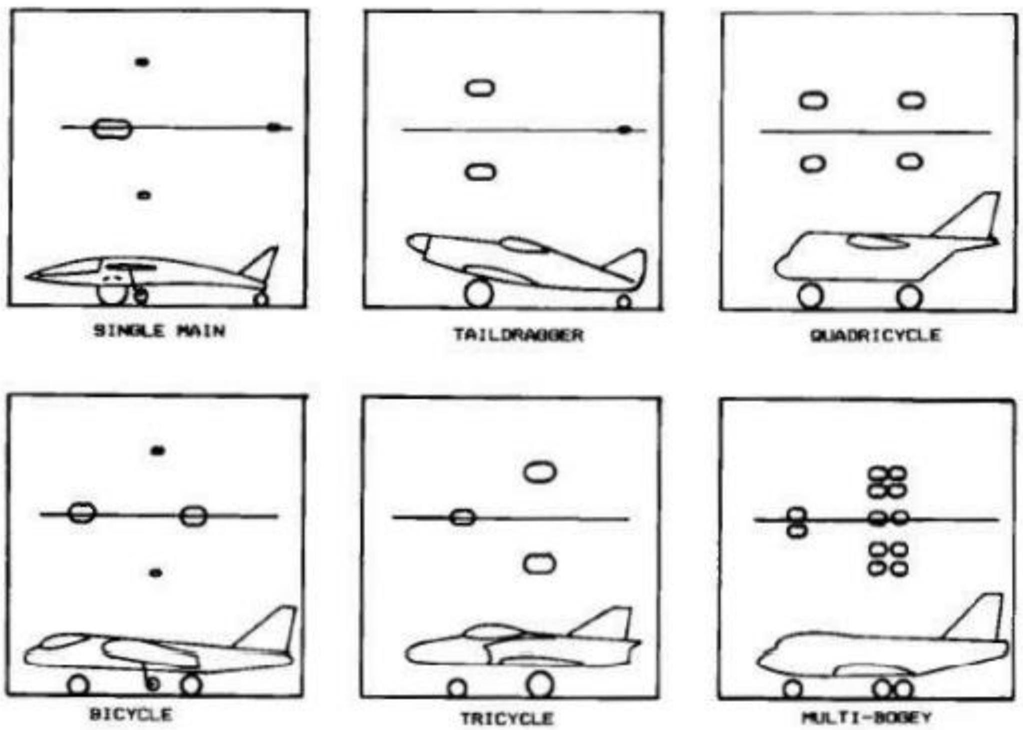


Figure 5.1- Landing Gear Arrangements

The “taildragger” landing gear has two main wheels forward of the c.g. and an auxiliary wheel at the tail. Taildragger gear is also called “conventional” landing gear, because it was the most widely used arrangement during the first 40 years of aviation. Taildragger gear provides more propeller clearance, has less drag and weight, and allows the wing to generate more lift for rough-field operation than does tricycle gear.

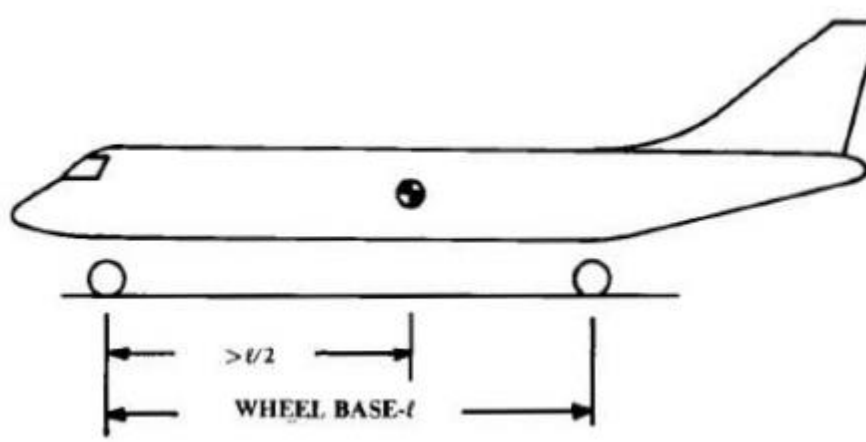


Figure 5.2 – Bicycle Landing Gear

The requirements for tail dragger gear are shown in Fig. below. However, taildragger landing gear is inherently unstable. If the aircraft starts to turn, the location of the c.g. behind the main gear causes the turn to get tighter until a "ground loop" is encountered, and the aircraft either drags a wingtip, collapses the landing gear or runs off the side of the runway. To prevent this the pilot of a taildragger aircraft must align the aircraft almost perfectly with the runway at touchdown and "dance" on the rudder pedals until the aircraft stops.

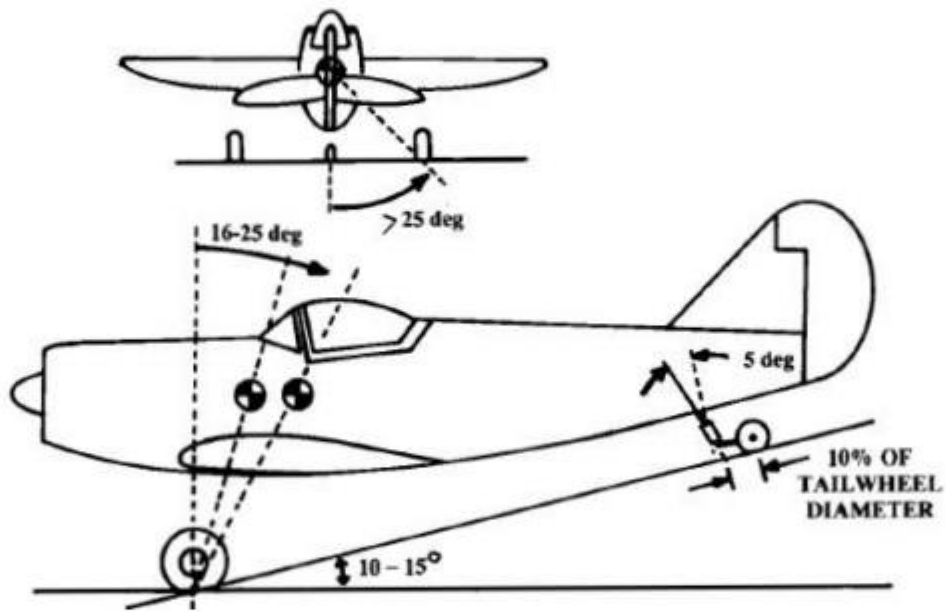


Figure 5.3 – Tail dragger landing gear

The most commonly used arrangement today is the "tricycle" gear, with two main wheels aft of the c.g. and an auxiliary wheel forward of the c.g. With a tricycle landing gear, the c.g. is ahead of the main wheels so the aircraft is stable on the ground and can be landed at a fairly large "crab" angle (i.e, nose not aligned with the runway). Also, tricycle landing gear improves forward visibility on the ground and permits a flat cabin floor for passenger and cargo loading.

Quadricycle gear is much like bicycle gear but with wheels at the sides of the fuselage. Quadricycle gear also requires a flat takeoff and landing attitude. It is used on the B-52 and several cargo planes where it has the advantages of permitting a cargo floor very low to the ground.

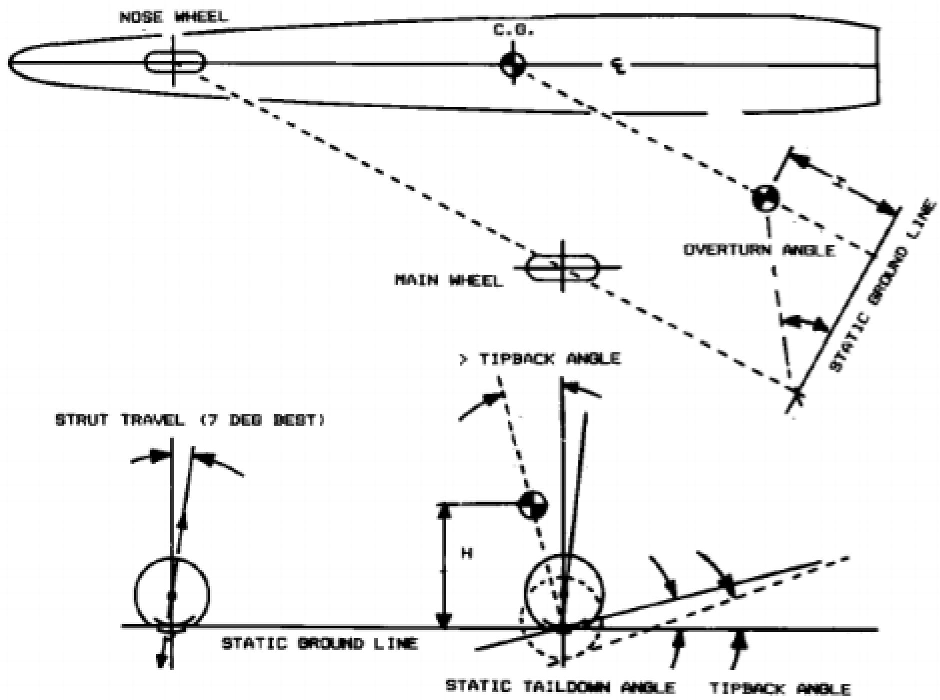


Figure 5.4 – Tricycle landing gear geometry

The gear arrangements described above are also seen with two, four or more wheels in place of the single wheels shown in figure 5.1. as aircraft weights become larger, the required wheel size for a single wheel capable of the holding the aircraft's weight becomes too large. Then multiple wheels are used to share the load between reasonably-sized tires.

Also, it is very common to use twin nose-wheels to retain some control in the event of a nose-wheel flat tire. Similarly, multiple main wheels (i.e., total of four or more) are desirable for safety. When multiple wheels (i.e., total of four or more) are desirable for safety. When multiple wheels are used in tandem, they are attached to the end of the shock-absorber strut.

Typically, an aircraft weighing under about 50,000 lb will use a single main wheel per strut, although for safety in the event of a flat tire it is always better to use two wheels per strut. Between 50,000 and 150,000 lb, two wheels per strut are typical. Two wheels per strut are sometimes used for aircraft weighing up to about 250,000 lb.

Between aircraft weights of about 200,000 and 400,000 lb the four-wheel bogey is usually employed; for aircraft over 400,000 lb, four bogeys, each with four or six wheels, spread the total aircraft load across the runway pavement.

Except for light aircraft and a few fighters, most aircraft use twin nose-wheels to retain control in the event of a flat nose tire. Carrier-based aircraft must use twin nose-wheels at least 19 inches in diameter to straddle the catapult-launching mechanism. The massive C-5 employs four nose-wheels to spread the tire load, permitting operation off of relatively soft fields.

Guidelines for layout of a bicycle landing gear are shown in figure 5.2. the tail-down angle should be about 10-15 deg with the gear in the static position (i.e., tires and shock absorbers compressed the amount seen when the aircraft is stationary on the ground at takeoff gross weight).

The c.g. (most forward and most aft) should fall between 16-25 deg back from vertical measured from the main wheel location. If the c.g. is too far froward the aircraft will tend to nose over, and if it is too far back it will tend to groundloop.

To prevent the aircraft from overturning the main wheels should be laterally separated beyond a 25 deg angle off the c.g., as measured from the rear in a tail-down attitude.

The layout of tricycle landing gear is as shown in figure 5.4 is even more complex. The length of the landing gear must be set so that the tail doesn't hit the ground on landing. This is measured from the wheel in the static position assuming an aircraft angle of attack for landing which gives 90% of the maximum lift. This ranges from about 10-15 deg for most types of aircraft.

5.2.1 SHOCK ABSORBERS–TYPES

The landing gear must absorb the shock of a bad landing and smooth out the ride when taxiing. The more common forms of shock absorber are shown in Figure.5.5. The tires themselves provide some shock-absorbing ability by deflecting when a bump is encountered. Sailplanes and a few homebuilt aircraft have been built with rigid axles, relying solely upon the tires for shock absorbing. Many World War I fighters used a rigid axle mounted with some vertical movement. The axle was attached to the aircraft with strong rubber chords The oleo pneumatic shock strut, or "oleo," is the most common type of shock-absorbing gear in use today (Fig. 3.28). The oleo concept was patented in 1915 as a recoil device for large cannons

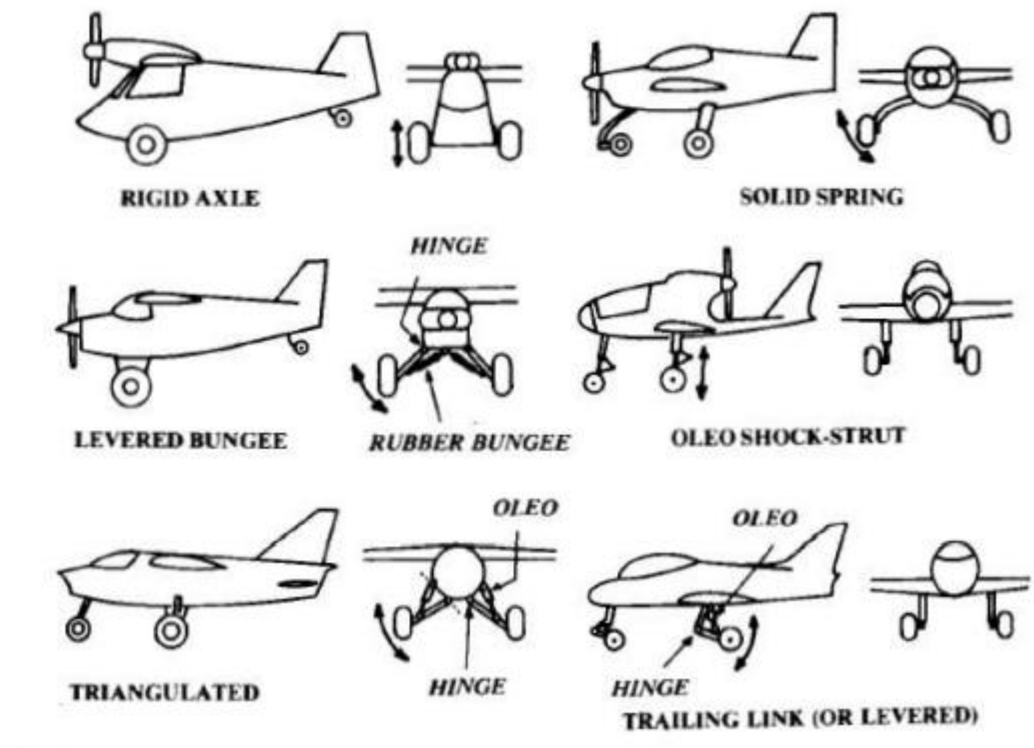


Figure 5.5 – Gear/shock arrangements

The oleo combines a spring effect using compressed air with a damping effect using a piston which forces 011 through a small hole (orifice). For maximum efficiency, many oleos have a mechanism for varying the size of the orifice as the oleo compresses the triangulated gear is similar to the levered bungee gear.

When the triangulated gear is deflected, an oleo pneumatic shock absorber is compressed. This provides a leveraged effect in which the oleo cans b~ shorter than the required wheel travel. This is especially useful for earner-based aircraft such as the A-7 that require large amounts of wheel travel to absorb the carrier-landing impact loads.

On a triangulated gear, the oleo can be replaced without removing the wheel assembly. The wheel lateral and braking loads are carried by the solid gear legs, which reduces the oleo weight. However, the complete triangulated gear is usually a little heavier than the oleo shock-strut gear. Also, there is a tire-scrubbing effect that shortens tire life.

The triangulated gear is sometimes seen on smaller aircraft using rubber blocks or springs in compression instead of an oleo pneumatic shock absorber. The rubber blocks or springs can be inside the fuselage which Streamlines the exposed part of the gear but requires the gear leg to support the aircraft's weight in a cantilevered fashion. This increases the gear weight

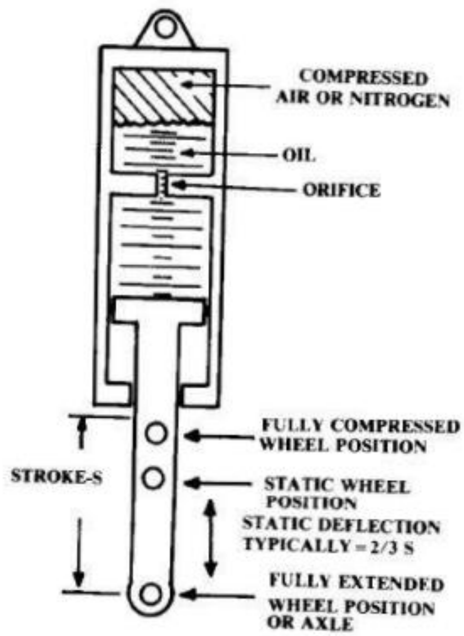


Figure 5.6 – Oleo shock absorber (most simple type)

5.2.2 STROKE DETERMINATION:

The required deflection of the shock-absorbing system (the "stroke") depends upon the vertical velocity at touchdown, the shock-absorbing material and the amount of wing lift still available after touchdown. As rough rule-of-thumb, the stroke in inches approximately equals the vertical velocity at touchdown in (ft/s). This kinetic energy is absorbed by the work of deflecting the shock absorber and tire.

$$KE_{vertical} = \left(\frac{1}{2}\right)\left(\frac{W_{landing}}{g}\right) V_{vertical}^2$$

Where W= total aircraft weight g= 32.2 ft/s2 If the shock absorber were perfectly efficient, the energy absorbed by deflection would be simply the load times the deflection. Actual efficiencies of shock absorbers range from 0.5-0.9. The actual energy absorbed by deflection is defined in Eq

$$KE_{\text{absorbed}} = \eta L S$$

where η= shock-absorbing efficiency

L = average total load during deflection (not lift!)

S = stroke

$$\left(\frac{1}{2}\right)\left(\frac{W_{\text{landing}}}{g}\right)V_{\text{vertical}}^2 = (\eta L S)_{\substack{\text{shock}\\\text{absorber}}} + (\eta_T L S_T)_{\text{tire}}$$

$$N_{\text{gear}} = L/W_{\text{landing}}$$

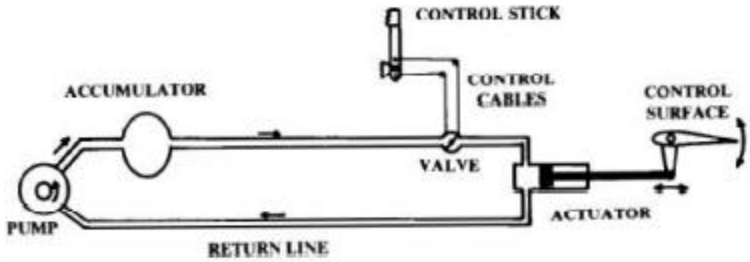
$$S = \frac{V_{\text{vertical}}^2}{2g\,\eta N_{\text{gear}}} - \frac{\eta_T}{\eta} S_T$$

5.3 AIRCRAFT SUBSYSTEMS

Aircraft subsystems include the hydraulic, electrical, pneumatic, and auxiliary emergency power systems. Also, the avionics can be considered a subsystem (although to the avionics engineers, the airframe is merely the "mobility subsystem" of their avionics package) In general, the subsystems do not have a major impact on the initial design layout. However, later in the design cycle the configuration designer will have to accommodate the needs of the various subsystems, so a brief introduction is provided below. No attempt is made to provide examples or rules of thumb because the subsystems hardware varies widely between different classes of aircraft.

5.3.1. Hydraulics:

Hydraulic fluid, a light oil-like liquid, is pumped up to some specified pressure and stored in an "accumulator" (simply a holding tank).



F***igure 5.7 – Simplified Hydraulic system***

When the valve is opened, the hydraulic fluid flows into the actuator where it presses against the piston, causing it to move and in turn moving the control surface. To move the control surface the other direction, an additional valve (not shown) admits hydraulic fluid to the back side of the piston. The hydraulic fluid returns to the pump by a return line.

To obtain rapid response, the valve must be very close to the actuator. The valve therefore cannot be in or near the cockpit, and instead is usually attached to the actuator. In most current designs the pilot's control inputs are mechanically carried to the actuator by steel cables strung from the control wheel or rudder pedals to the valves on the actuators.

In many new aircraft the pilot's inputs are carried electronically to electromechanical valves ("fly-by-wire"). Hydraulics are used for aircraft flight control as well as actuation of the flaps, landing gear, spoilers, speed brakes, and weapon bays. Flight-control hydraulic systems must also include some means of providing the proper control "feel" to the pilot. For example, the controls should become stiffer at higher speeds, and should become heavier in a tight, high-g turn. Such "feel" is provided by a combination of springs, bob weights, and air Bellows.

In most cases the hydraulic system will impact the aircraft conceptual design only in the provision of space for the hydraulic pumps, which _are usually attached to the engines. These should be copied from a similar aircraft if better information is not available.

5.3.2 ELECTRICAL SYSTEM

An aircraft electrical system provides electrical power to the avionics, hydraulics, environmental-control, lighting, and other subsystems the electrical system consists of batteries, generators, transformer-rectifiers ("TR's"), electrical controls, circuit breakers, and cables. Aircraft generators usually produce alternating current (AC) and are located on or near the engines. TR's are used to convert the alternating current to direct current (DC). Aircraft batteries can be large and heavy if they are used as the only power source for starting.

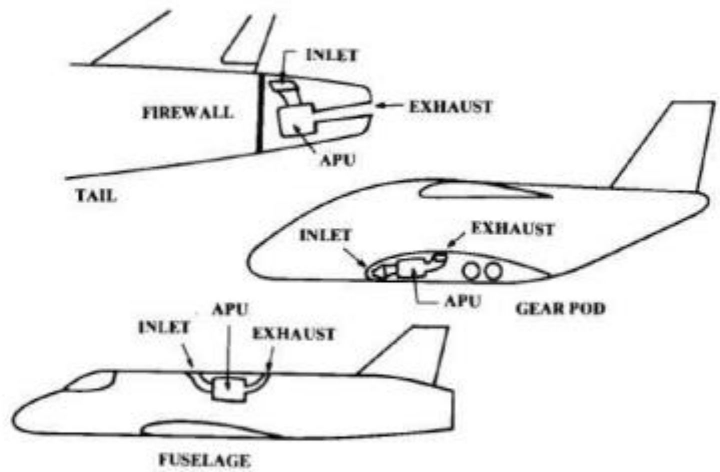


Figure 5.8 – APU Installation

5.3.3. PNEUMATIC SYSTEM

The pneumatic system provides compressed air for pressurization, environmental control, anti-icing, and in some cases engine starting. Typically, the pneumatic system uses pressurized air bled from the engine compressor. This compressed air is cooled through a heat exchanger using outside air. This cooling air is taken from a flush inlet inside the inlet duct (i.e., inlet secondary airflow) or from a separate inlet usually located on the fuselage or at the front of the inlet boundary-layer diverter. The cooled compressor air is then used for cockpit pressurization and avionics cooling. For anti-icing, the compressor bleed air goes uncooled through ducts to the wing leading edge, inlet cowls, and windshield.

Compressed air is sometimes used for starting other engines after one engine has been started by battery. Also, some military aircraft use a ground power cart that provides compressed air through a hose to start the engine

5.3.4. AUXILIARY/EMERGENCY POWER

Large or high-speed aircraft are completely dependent upon the hydraulic system for flight control. If the hydraulic pumps stop producing pressure for any reason, the aircraft will be uncontrollable. If the pumps are driven off the engines, an engine flame-out will cause an immediate loss of control. For this reason, some form of emergency hydraulic power is required. Also, electrical power must be retained until the engines can be restarted. The three major forms of emergency power are the ram-air turbine (RAT), monopropellant emergency power unit (EPU), and jet-fuel EPU. The ram-air turbine is a windmill extended into the slipstream. Alternatively, a small inlet duct can open to admit air into a turbine The monopropellant EPU uses a monopropellant fuel such as hydrazine to drive a turbine.

The available monopropellants are all toxic and caustic, so monopropellant EPU's are undesirable for operational considerations. However, they have the advantage of not requiring any inlet ducts and can be relied upon to provide immediate power regardless of aircraft altitude, velocity, or attitude. Monopropellant EPU's must be located such that a small fuel leak will not allow the caustic fuel to puddle in the aircraft structure, possibly dissolving it Jet-fuel EPU's are small jet engines that drive a turbine to produce emergency power. These may also be used to start the main engines ("jet-fuel starter"). While they do not require a separate and dangerous fuel, the jet-fuel EPU's require their own inlet duct.

5.3.5. AVIONICS

Avionics (a contraction of "aviation electronics") includes radios, flight instruments, navigational aids, flight control computers, radar, and other aircraft sensors such as infrared detectors. For initial layout, it is necessary to provide sufficient volume in the avionics bays. Also, the nose of the aircraft should be designed to hold the radar. On the average, avionics has a density of about 30-45 lb/ft3 • The required avionics weight can be estimated from the aircraft empty weight (We), which is known at this point

5.4. CABIN PRESSURIZATION AND AIR CONDITIONING

• At cruise altitude temperature drops to -50° C and below, and the pressure and density reduce to less than one fifth and one fourth of sea level values.

• Above 14000 ft altitude, the Aircraft interior environment must be controlled for crew and passenger comfort as well as equipment protection.

• Aircraft Environmental Control System (ECS) consists of cabin pressurization and Air conditioning

• The cabin interior pressure maintained at sea level conditions is ideal but expensive. Cabin pressurization is like inflating a balloon

• The major differential between the outside and inside pressure requires structural reinforcement, which makes an Aircraft heavier and more expensive. Generally, cabin pressure is maintained at 8000 ft altitude (maximum 8.9 psi)

• Passengers feel it in their ears as they adjust to the change of pressure• Cabin Air conditioning is a integral part of ECS along with cabin pressurization • The engine compressor, which is bleed at an intermediate stage with sufficient pressure and temperature becomes contaminated and must be cleaned with moisture removed to an acceptable level

• Maintaining proper humidity is also part of ECS

• The bleed air is then mixed with cool ambient air, in addition there is a facility for refrigeration

• The heat exchanger, water condenser, valves and sensors comprise a complex system • Avionic black boxes heat up and must be maintained at a level that keeps equipment functioning

• The equipment bay is below the floor, typically a separate cooling system is employed to keep the equipment cool

• Military Aircraft ECS uses, boot strap refrigeration system, recently it is also used in civil Aircraft

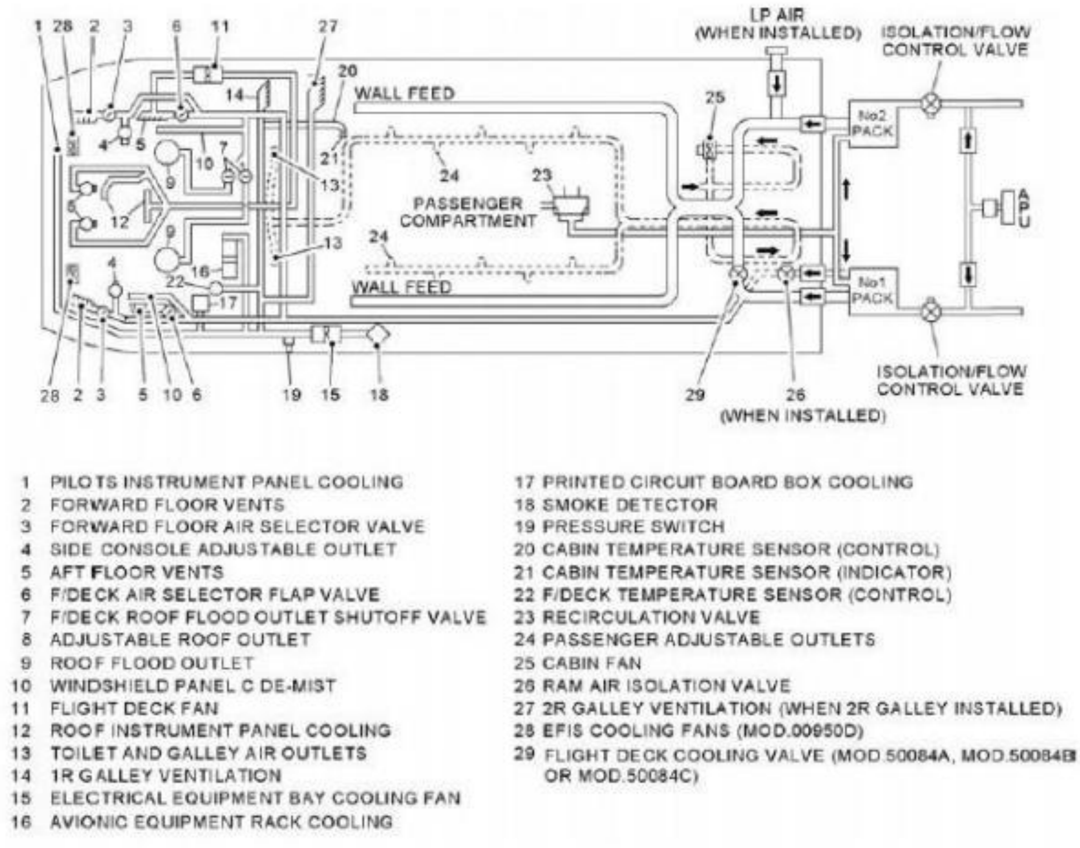


Figure 5.9 -Air Conditioning System

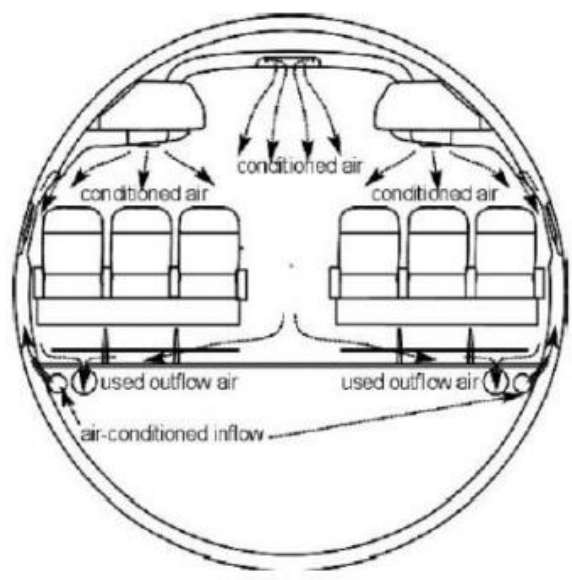


Figure 5.10 – Cabin Airflow ECS