Dept. of Aeronautical Engineering

U20AE402 Aircraft Systems and Instruments

Part A Q&A

Unit 1 – Aircraft Systems

1. What is the purpose of the 'pressure Regulator' in hydraulic system?
    - Pressure regulators are pressurized by constant-delivery type pumps.
    - One purpose of the pressure regulator is to manage the output of the pump to maintain system operating pressure within a predetermined range.
    - The other purpose is to permit the pump to turn without resistance (termed unloading the pump) at times when pressure in the system is within normal operating range.
2. What is the purpose of "Selector Valve" in hydraulic system?
    - Selector valves are used to control the direction of movement of an actuating unit.
    - A selector valve provides a pathway for the simultaneous flow of hydraulic fluid into and out of a connected actuating unit.
    - One port of the typical selector valve is connected with a system pressure line for the input of fluidpressure.
    - A second port of the valve is connected to a system return line for the return of fluid to thereservoir.
    - The ports of an actuating unit through which fluid enters and leaves the actuating unit areconnected by lines to other ports of the selector valve.
3. What are the advantages of pneumatic system over hydraulic system? .(Nov/Dec08)
    - Simplicity of design and control—Machines are easily designed using standard cylinders and other components.
    - Reliability—Pneumatic systems generally have long operating lives and requires littlemaintenance.
    - Gas absorbs excessive force, whereas fluid in hydraulics directly transfers force.Compressed gas can be stored, so machines still run for a while if electrical power iscost.
    - Safety—there is a very low chance of fire compared to hydraulic oil.
4. List out the different types of selector valves in hydraulic systems. .(Nov/Dec10)

    Selector valves are used in a hydraulic system todirect the flow of fluid.
    Three general typesof selector valves are
    (a) poppet,(b) slide,and (c) solenoid-operated valves
5. Differentiate between the check valve and non-return valve.

    A check valve, clack valve, non-return valve or one-way valve is a mechanical device, avalve, which normally allows fluid (liquid or gas) to flow through it in only one direction.

6. Differentiate between springs oleo struts and air oleo struts?
    - In spring oleo struts, the spring supports the A/C weight on the ground and duringTaxiing and oleo strut aborts the shock of landing.
    - In air oleo struts, the air supports the A/C weight on the ground and absorbs shocksduring taxiing and oleo strut aborts the shock of landing.
7. Define Pascal Law.

   It states that pressure applied anywhere in a confined incompressible fluid is transmitted equally in all directions throughout the fluid.
8. What is the difference between hydraulic and pneumatic systems?(May/June07)

S.NO.	Hydraulic System	Pneumatic System
1	It is designed as closed system	It is designed as open system
2	It is used liquid for operation.	It is used air for operation.
3	Heavy weight	Less weight
4	Higher response	Low response

9. List out main requirements of hydraulic fuels?
    - Low viscosity
    - High flash point
    - High Fire point
    - Good chemical and environmental stability
10. What is the disadvantages of Pneumatic system?
    1. The system cannot be re-charged during flight,
    2. Operation is limited by the small supply of bottled air.
    3. Such an arrangement cannot be used for the continuous operation of a system
11. What is the difference between tricycle landing gear and conventional landing gear?

    Try cycle landing gear:
    1. Allows more forceful application of the brakes without nosing over when braking, which enables higher landing speeds.
    2. Provides better visibility from the flight deck, especially during landing and ground maneuvering.
    3. The nose gear of a few aircraft with tricycle-type landing gear is not controllable. It simply casters as steering is accomplished with differential braking during taxi.
    4. However, nearly all aircraft have steerable nose gear. On light aircraft, the nose gear is directed through mechanical linkage to the rudder pedals.
    5. Heavy aircraft typically utilize hydraulic power to steer the nose gear.

    Conventional landing gear:
    1. Tail wheel-type landing gear is also known as conventional gear because many early aircraft use this type of arrangement.
    2. The main gear are located forward of the center of gravity, causing the tail to require support from a third wheel assembly.
    3. A few early aircraft designs use a skid rather than a tail wheel.
    4. This helps slow the aircraft upon landing and provides directional stability.
    5. The resulting angle of the aircraft fuselage, when fitted with conventional gear, allows the use of a long propeller that compensates for older, underpowered engine design.

12. What is thermal relief value?

    A thermal relief value is similar to a regular system relief value bit such values are installed in parts of the hydraulic system where fluid pressure is trapped and may need to be relieved because of the increase caused by higher temperatures.

13. Differentiate between single-acting and double acting actuating cylinder?

    A single acting actuator is normally used as a locking device the lock being engaged by spring pressure and released by hydraulic pressure. The double acting actuator is used in most aircraft systems eg landing gear.

14. Differentiate between single disk brake and multiple disk brakes?

    Single disk brakes are used in smaller aircraft single disk may be conducted with a many separate pistons and linings as needed for the airplane. Each piston in equipped with separate sets of linings, which bear against the brake disk when the brake see applied multiple disk brakes are used in large aircraft. Braking action is produced by hydraulic pressures forcing the pistons against the pressures plate, which, in turn, forces the disk together and create friction between the retracting and stationary disks.

15. Differentiate between expander – shoe brake and expands – tube brake?

    Expander shoe brake: Relation of break drum adds braking energy to the brake shoes and makes them operate more effectively & with Len effort by the pilot. They are also known as serve brakes. Expander tube break: The pressure of hydraulic fluid in the tube forces the blocks radically outward against the break drum.

16. Differentiate between open and closed hydraulic system?

    An open system is one having fluid flow but no appreciable pressure in the system whenever the actuating mechanisms are idle. It’s simple but only one service can be operated by this system at a time. A closed system is one that directs fluid flow to the main system manifold and builds up pressure in that portion of the system the leads to all the selector values. Its bit complicated but more than one service can be operated by this system at a time.

17. Classify air pressure sources?

    1. Super charger
    2. Turbo charger
    3. Engine bleed air
    4. Independent cabin compressors.

18. What is a moisture control?

    The great reduction in temperature causes the moisture in the air to condense and thin moisture is removed by means of a water repeater.

19. What is tunnion?

    The tunnion is the portion of landing gear assembly attached to the airframe. The trunnion in supported at its ends by bearing assemblies which allows the gear to pivot during retraction and extension.

20. Classify the types of retraction system? (April/May19)

    - ✈ Mechanical retraction system
    - ✈ Electrical retraction system
    - ✈ Hydraulic retraction system

Unit II Airplane Control System

1. Name the three primary controls used in an air plane.(April/May19)
   - Aileron – to provide rolling motion
   - Elevator – to provide Pitch Up or Pitch Down motion
   - Rudder – to provide Yawing motion
2. What is the purpose of 'auto pilot system' installed in an air plane?
   - To reduce the work strain and fatigue of controlling the aircraft during long flights.
   - In the manual mode, the pilot selects each manoeuvre and makes small inputs into an autopilot controller.
   - The autopilot system moves the control surfaces of the aircraft to perform the manoeuvre.
   - In automatic mode, the pilot selects the attitude and direction desired for a flight segment. The autopilot then moves the control surfaces to attain and maintain these parameters
3. What is fly by wire system? (Nov/Dec09)

   For a fly by wire system all the inputs are converted corresponding electrical signals andtransmitted to the actuators through electrical wires. Some of advantage of fly by wire system:
   - Weight saving
   - Improved handling
   - Fuel saving
   - Reduced maintenance
4. What do you mean by active control technology? Give at least three examples?

   Activate control technology helps to improve the handling of aircraft and to reduce thetime lag or control delays by increasing the no. of computers, etc., in the aircraft (i.e.redundancy). This advance concept in applicable to following e.g.
   - Fly by wire
   - Control configured vehicles
   - Automatic flight control system.
5. Name any four modern control systems?
   - Fly by wire (computer):- May be Analog computer or digital computer
   - Fly by optics (light):-
   - Power by size (user electro-hydraulic actuators
   - Intelligent flight control system
6. What is the function of Autopilot system?
   - Provide for one-, two-, or three-axis control of an aircraft.
   - Single axis autopilot control the ailerons only and usually found on light aircraft.
   - Two-axis autopilots that control the ailerons and elevators.
   - Three-axis autopilots control the ailerons, elevators, and the rudder.
   - Two-and three axis autopilot systems can be found on aircraft of all sizes.
7. What is the function of Engine control system?
   - FADEC works by receiving multiple input variables of the current flight condition including air density, throttle lever position, engine temperatures, engine pressures, and many other parameters.
   - The inputs are received by the EEC and analysed up to 70 times per second.

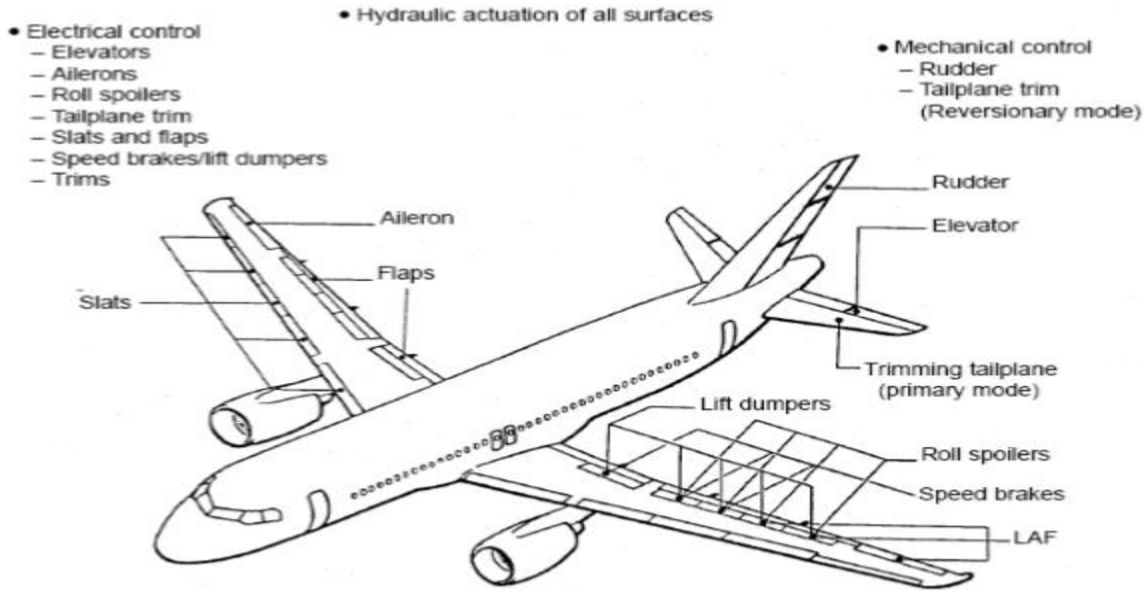
- Engine operating parameters such as fuel flow, stator vane position, bleed valve position, and others are computed from this data and applied as appropriate.
- It controls engine starting and restarting.
- Its basic purpose is to provide optimum engine efficiency for a given flight condition.

8. What is the difference between flyby wire and conventional control system?

S.NO.	Fly by wire system	Conventional system
1	It is used wire for transmission of signal.	It is used chain and pulleys for transmission of signal.
2	Higher performance	Lower performance
3	Less Maintenance	Periodical maintenance required.
4	Less Weight	Heavy weight.

9. Define flight control system. List out the different flight controls used in larger airplane.

A control system is a collection of mechanical and electronic equipment that allows an aircraft to be flown with exceptional precision and reliability. A control system consists of cockpit controls, sensors, actuators (hydraulic, mechanical or electrical) and computers



10. What are the merits and demerits of analog and digital fly by wire flight control system? .(April/May19)

Analog Fly by wire:

- Fly-by-wire replaces hydro mechanical or electromechanical flight control systems with electronic circuits.
- The control mechanisms in thecockpit now operate signal transducers, which in turn generate the appropriate electronic commands.
- These are next processed by an electronic controller with an analog signal.

Digital Fly by wire:

- A digital fly-by-wire flight control system is similar to its analog counterpart.
- The signal processing is done by digital computers and the pilot literally cans "fly-via-computer". It increases the flexibility of the flight control system.
- The digital computers can receive input from any aircraft sensor.
- This also increases the electronic stability, because the system is less dependent on the values.

11. What is meant by Flapron?

    In addition to controlling the roll or bank of an aircraft, as do conventional ailerons, both Flapron can be lowered together to function similarly to a set of flaps.A mechanical device called a "mixer" is used to combine the pilot's input into the Flapron.

12. Define Autopilot. .(Nov/Dec11)

    An aircraft automatic pilot system controls the aircraft without the pilot directly manoeuvring the controls. The autopilot maintains the aircraft's attitude and/or direction and returns the aircraft to that condition when it is displaced from it. Automatic pilot systems are capable of keeping aircraft stabilized laterally, vertically, and longitudinally.

13. What is stabilators, ruddervators and flaperons?
    - ✈ STABILATOR = STABILIZER + ELEVATOR
    - ✈ RUDDERVATORS = RUDDERS +ELEVATORS
    - ✈ FLAPERONS = FLAP + AILERONS

14. What is aileron differential control system?

    Movement of control stick moves one ailerons up greater than the other down words.

15. What is the use of yaw dampers in rudder control system?

    Yaw damper systems operate continuously in flight to improve the airplane's directional stability and turn coordination. Dampers actuators are powered hydraulically

16. Classify at least truce engine control system?
    - ➢ FADEC (Full Authority Digital Electronic/Engine control)
    - ➢ ECU (Electronic Engine Control)
    - ➢ ECU can be manually over ridden by FADEC

17. What do you understand by push pull rod system? (Nov/Dec09)

    A stiff rod or hollow tube in an aircraft control system that moves a control surface by either pushing it or pulling it.

18. What is the purpose of autopilot?

    The purpose of an automatic pilot system is primarily to reduce the work, strain, and fatigue of controlling the aircraft during long flights. To do this the automatic pilot system performs several functions. It allows the pilot to maneuver the aircraft with a minimum of manual operations. While under automatic control the aircraft can be made to climb, turn, and dive with small movements of the knobs on the autopilot controller.

19. What is the function of autopilot? .(Nov/Dec10)

    Autopilot systems provide for one, two, or three axis control of the aircraft. Some autopilot systems control only the ailerons (one axis), others control ailerons and elevators or rudder (two axis). The three-axis system controls ailerons, elevators, and rudder.

20. What is the main components of autopilot?

    All autopilot systems contain the same basic components: (1) Gyros, to sense what the airplane is doing; (2) servos, to move the control surfaces; and (3) an amplifier, to increase the strength of the gyro signals enough to operate the servos. A controller is also provided to allow manual control of the aircraft through the autopilot system.

UNITIII -ENGINE SYSTEMS

1. State the purpose of 'Dual magneto' ignition in air craft piston engine.
   The dual magneto incorporates two magnetos contained in a single housing. One rotating magnet and a cam are common to two sets of breaker points and coils. Two separate distributor units are mounted in the magneto. Many older single-row radial engine aircraft ignition systems employ a dual-magneto system, in which the right magneto supplies the electric spark for the front plugs in each cylinder, and the left magneto fires the rear plugs. Engines have old fashion but reliable fixed-timed dual magneto ignition systems.
2. What is meant by 'Hot Start' in turbojet engine?
   During engine start, the compressor is very inefficient, as already discussed. If the engine experiences more than the usual difficulty accelerating, the engine may spend a considerable time at very low RPM (sub-idle). Normal engine cooling flows will not be effective during sub-idle operation, and turbine temperatures may appear relatively high. This is known as a hot start .The AFM indicates acceptable time/temperature limits for EGT during a hot start. More recent, FADEC-controlled engines may incorporate auto-start logic to detect and manage a hot start.
3. How do you select the ignition system for an aircraft?
   The ignition system for an aircraft must be capable of delivering a high voltage spark to each cylinder under all condition. The spark must be created and delivered at the correct moment during the operating cycle. The ignition system must have high degree of reliability.
4. What are the advantages of air turbine starters? (Nov/Dec08)
   - Self-contained starts possible for large engines
   - Very high torque-to-weight ratio
   - Quick starts possible for military
5. Why mineral base fluids are preferable in small aircrafts hydraulic systems?
   - It is petroleum based hydraulic fluids
   - It do not mix with vegetable base
   - Cost is less
6. List out the aircraft engine lubrication oil requirements.
   - The oil should highly viscous
   - The oil must able to withstand the high temperatures
   - It should be in light color
7. Give main requirements of hydraulic fuels.
   - Low compressibility (high bulk modulus)
   - Fast air release
   - Low foaming tendency
   - Low volatility
8. Distinguish between fuel system of piston and jet engine (May/June07)

Sl.No.	Piston Engine	Jet Engine
1	Spark plug is available.	No Spark plug is available.
2	Low thrust generated	Higher thrust generated
3	Suitable for low altitude	Suitable for higher altitude
4	It is also called as Reciprocating Engine	It is also called as Gas Turbine Engine.
5	Eg: gravity feed system, pressure	Engine driven pump system

	feed system	

9. List out the main requirements of a typical starting system of a gas turbine engine.
   - The starting system must capable of producing initial torque.
   - It must senses the speed and disengage the unit after starting
   - The starting system should be light weight.
10. List down lubricants used in the aircraft lubrication systems.
    - Vegetable based hydraulic fluid,
    - Mineral based hydraulic fluid,
    - Phosphate ester based hydraulic fluid,
    - Synthetic based hydraulic fluid
11. What are the main functions of engine oil in the oil system? .(Nov/Dec10)

    There are at least five main functions of engine oil:

    Cool--absorbs heat as it is circulated, cooling the engine.

    Lubricate--creates a viscous barrier between moving parts that reduces friction, which means less heat and longer life for those parts.

    Clean--small particles of dirt or other contaminants are suspended in oil and carried away to be filtered out.

    Seal--helps to seal the space between the pistons and the cylinder walls so that compression is more effective and power is not lost during combustion.

    Protect--coats parts to provide a layer of protection against corrosion/rust.
12. Differentiate between nigh tension ignition system & low tension ignition system?

    - Magneto Ignition system operate on the principles of electro magnetic induction. They can be high tension & low tension ignition system.

    - High tension magnetic Ignition system High voltages are induced either by rotating the transformer windings between poles of permanent magnet or by rotating the magnet between fixed transformer windings car by rotating soft iron bass between fixed permanent magnets and transformers winding.

    - Low tension magnate Ignition system then system were developed far engineer having large no of better then high tension. In this, the low voltage impulses from the magneto primary are directly supplied to the distributor. The low tension magnet are suited on and off similar to the high tension magneto.
13. What is surge fuel tank?

    Surge fuel tanks are normally empty and are designed to contain fuel overflow & prevent fuel spillage particularly when fueling the aircraft.
14. What is vapor lock? .(April/May19)

    Vapor lock is a condition of fuel starvation that can occur in a reciprocating engine fuel system in which the fuel in the fuel line is heated enough to cause it to vaporize, forming a busle of fuel vapor in the lime blocking fuel from flowing to the engine.
15. A) Classify fuel system? B) Why do we need primers?

    a) Fuel systems are

    - Gravity feed fuel system

    - Pressure feed fuel system

    b) Non fuel injected reciprocating A/C engines must often be primed before Starting because carburettor is not functioning properly until the engine is running.
16. What is fuel cross feed system?

On most multiengine air craft, the fuel manifold are connected in such a manner that any fuel tank may supply fuel to any engine, any tank can transfer fuel to other tank for balancing

17. What is the purpose of fuel boost over ride & scavenge pump in fuel system?

    The central using tank boost pumps will override the main-tank boost pump to supply fuel through the manifold to the engines. That's way it's known as fuel –boost over ride pump. Scavenge pump helps to prevent water from accumulating in the tanks low points. Thus avoids corrosion problems.

18. Clarity turbine engine ignition system?
    1. Capacitor type ignition system (jet)
    2. Electronic ignition system (jet)
    3. Battery ignition system P
    4. Magnetic system (High tension)
    5. Magnetic system (Low tension)
19. Clarity reciprocating engine starting system?
    a. Cartridge starter
    b. Hand inertia starter
    c. Electric inertia starter
    d. Come inertia starter
    e. Direct cranking starter
20. What is fuel Jettison or dumping system?

    In this system fuel from the tanks is continuous from using tip to using tip, with each end terminating at a fixed fuel jettison nozzle. The nozzle value is an electrically ape rated value controlled from the cockpit. After fuel passer through the nozzle value, it flows into the jettison nozzle to be discharged in to the air the jettison nozzle to be discharged in to the air.

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UNIT-IV -AIRCONDITIONING AND PRESSURIZATION SYSTEM

1. What is the function of the primary heat exchanger bypass valve in air cycle system?
   - It acts similarly to the radiator in an automobile.
   - To reduces the temperature of the air inside the system.
2. State the major components in vapour cycle system (FREoN).(Nov/Dec08)
   - Evaporator - The Freon boils in the evaporator at a temperature lower than the Cabin Temperature. The result is that the Freon extracts heat from the cabin air
   - Compressor - The compressor increases the pressure of the Freon in vapor form.
   - Condenser - When heat is removed from the highpressure gas, Freon is converted to aliquid
   - Expansion valve - Lowers Freon pressure and, thus, Freon temperature
   - Receiver
   - Sub Cooler
3. List out the types of overheat detectors used in fire protection system.
   - Thermal switch system
   - Fenwal spot detector
   - Thermocouple system
4. What are the methods available to provide heated air to the thermal anti-icing system?
   - Anti icing using combustion heater
   - Anti icing using exhaust heater
   - Anti icing using engine bleed air,
5. Distinguish between air cycle cooling and vapour cycle cooling.

   Air cycle machine:- The turbine, compressor unit by which air is cooled is called air cycle machine(ACM) The ACM user compression and expansion of air to lower the temperature of cabin air.

   Vapor cycle machine: - User refrigerant instead of air the vapor cycle machine in a closed system usury the evaporation and condensation of Freon to remove heat from the cabin interior.
6. What is the need for pressurizing the aircraft cabin? .(Nov/Dec11)

   Cabin pressurization is the pumping of compressed air into an aircraft cabin to maintain a safe and comfortable environment for crew and passengers when flying at altitude. Pressurization becomes necessary at altitudes beyond 10,000 feet (3,000 m) above sea level to protect crew and passengers from the risk of a number of physiological problems caused by the low outside air pressure above that altitude.
   - Hypoxia.
   - Altitude sickness.
   - Decompression sickness.
   - Barotrauma.
7. How is cabin pressure dumped?

   All exhaust air is dumped to atmosphere via an outflow valve, usually at the rear of the fuselage. This valve controls the cabin pressure and also acts as a safety relief valve, in addition to other safety relief valves.
8. Differentiate between the anti-icing and de-icing method used in aircrafts.

   De-icing is defined as removal of snow, ice or frost from a surface. De-icing means removing ice that has already farmed.

Anti-icing prevent adhesion of ice to make mechanical removal easier. Thermal anti-icing heated air flowing through passages in the leading edge of wings, Stabilizers and engine cowlings tee pre unit the formation of ice

9. What do you mean by purging the system?

   In vapor cycle refrigeration system, purging means releasing the refrigerant. In fuel system, purging means draining the fuel from tank by introducing inert gas as co2 or N2 to the tank. In oxygen system, purging means releasing oxygen from the system.

10. What is shirt sleeve environment? (May/June07)

    In order to make the cabin environment comfortable for the air craft occupants, the cabin must normally be pressurized to maintain the cabin air pressure at the level reached at no higher than 800 it. This enables the crew and passengers to function without the uses of supplemental oxygen and, with adjustments of the cabin air temperature, allows them to be in a shirt sleeve" environment

11. Differentiate between super changer and turbo charger?

    A supercharger is an engine drive air pump; mechanically drive for engine, which compresses air for use by the engine in the combustion process.

    A turbocharger is used in a similar manner as a system charger except that the turbo charger is driven by exhaust gases from the engine, which driver an airCompressed to supply an air charge to the engine.

12. What is thermal anti-icing?

    Thermal anti-icing heated air flowing through passages in the leading edge of wings, Stabilizers and engine cowlings tee pre unit the formation of ice.

13. What is wind shield ice control?

    - By heating the wind shield
    - By spraying a fluid on the windshield, to remove ice and present the formation of any more ice

14. What is gasper system?

    The individual air- distributive system, also called the gasper system, routes only the cold air from the air conditionary packs to individually regulated outlets in the control and passenger cabins.

15. What is static balancing?

    To eliminate the effect of cross wind or side slip the static resource in duplicated and is known as static balancing

16. SAT (Static air temperature)?

    This is the tem the air at the surface of the aircraft would be at if there were no compression effects due to air craft is movement TAT (Total air temperature) in the temp. Of the air when it has been brought completely to set, as in the pilot tube.

17. How is cabin pressure dumped?

    All exhaust air is dumped to atmosphere via an outflow valve, usually at the rear of the fuselage. This valve controls the cabin pressure and also acts as a safety relief valve, in addition to other safety relief valves.

18. Briefly describe the components of a thermal switch fire detection system

    Temperature sensitive switches that complete a circuit at a specific temperature and trigger a warning.

19. Describe the components and operation of a Lindberg fire detection system

    A stainless steel tube contains an inert gas and a discrete material that absorbs some of the gas. When the tube heats up, gas is released raising pressure inside the tube activating a pressure switch.

20. How does a photoelectric smoke detector generate a warning of possible fire?
Smoke particles refract light in the unit, causing the photoelectric cell to produce electricity and cause an alarm signal

UNIT-VAIRCRAFT INSTRUMENTS

1. What is the function of 'air Speed indicator' as an aircraft instrument?
   - The airspeed indicator is a sensitive, differential pressure gauge which measures and shows promptly the difference between pitot or impact pressure, and static pressure, the undisturbed atmospheric pressure at level flight.
   - These two pressures will be equal when the airplane is parked on the ground in calm air.
   - When the airplane moves through the air, the pressure on the pitot line becomes greater than the pressure in the static lines.
   - This difference in pressure is registered by the airspeed pointer on the face of the instrument, which is calibrated in miles per hour, knots, or both
2. State the importance of engine instruments.
   - Engine instruments are those designed to measure operating parameters of the aircraft's engine(s).
   - These are usually quantity, pressure, and temperature indications. They also include measuring engine speed(s).
   - The most common engine instruments are the fuel and oil quantity and pressure gauges, tachometers, and temperature gauges.
3. Distinguish between engine instruments and navigation instruments.

   Engine instrument - are designed to measure the quantity and pressure of liquids (fuel and oils), r.p.m, and temperature.

   Navigation instruments - provides information that enables the pilot to guide the aircraft accurately along the definite courses.
4. What is the principle involved in air speed indicator? (May/June07)

   The airspeed indicator or airspeed gauge is an instrument used in an aircraft to display the aircraft's airspeed, typically in knots, to thepilot. Airspeed indicators work by measuring the difference between static pressure, captured through one or more static ports; and stagnation pressure due to "ram air", captured through a pitot tube.
5. What are the different types of aircraft pressure gauge?
   - oil *pressure gauge*
   - manifold *pressure gauge*
   - air pressure gauges
6. What is the working principles of electrical resistance thermometer? (May/June06)

   For most metals, electrical resistance changes as the temperature of the metal changes. This is the principle upon which a resistance thermometer operates. Typically, the electrical resistance of a metal increases as the temperature rises.
7. Define the properties of gyroscope.

   Rigidity

   The property which resists any force tending to change the plane of rotation of its rotor. This property is dependent on three factors: (i) the mass of the rotor, (ii) the speed of rotation, and (iii) the distance at which the mass acts from the centre, i.e. the radius of gyration.

Precession

The angular change in direction of the plane of rotation under the influence of an applied force. The change in direction takes place, not in line with the applied force, but always at a point ***90'*** away in the direction of rotation. The rate of precession also depends on three factors: (i) the strength and direction of the applied force, (ii) the moment of inertia of the rotor, and **(iii)** the angular velocity of the rotor. The greater the force, the greater is the rate of precession, while the greater the moment of inertia and the greater the angular velocity, the smaller is the rate of precession.

8. What are TAS and EAS? .(Nov/Dec11)

   The true airspeed (TAS; also KTAS, for *knots true airspeed*) of an aircraft is the speed of the aircraft relative to the air mass in which it is flying. The true airspeed is important information for accurate navigation of an aircraft.

   Equivalent airspeed (EAS) is the airspeed at sea level in the International Standard Atmosphere at
   which the dynamic pressure is the same as the dynamic pressure at the true airspeed (TAS) and altitude at which the aircraft is flying. In low-speed flight, it is the speed which would be shown by an airspeed indicator with zero error.

9. What is the principle involved in accelerometer.(Nov/Dec09)

   An accelerometer is a device that measures proper acceleration. The proper acceleration measured by an accelerometer is not necessarily the coordinate acceleration (rate of change of velocity).

10. Discuss the principle in which the temperature gauges functions.(Nov/Dec09)

    Thermometers filled with either a liquid such as mercury or an evaporating fluid as used in refrigerators in both cases the inside of the sensor head and the connecting tube arecompletely full any rise in temperature produces expansion or evaporation of the liquid so the sensor becomes pressurized. The pressure is related to the temperature and it may be indicated on a simple pressure gauge.

11. What are the navigation instruments?
    - VHF Direction Finder (VDF)
    - NDB non- directional beacon
    - ADF Automatic direction finder
    - GPS global positioning system

12. How can use measure RPM of engine?
    - By Electronic Tachometer
    - By electrical Tachometer
    - By Magnetic Tachometer.

13. What is the purpose of artificial horizon?

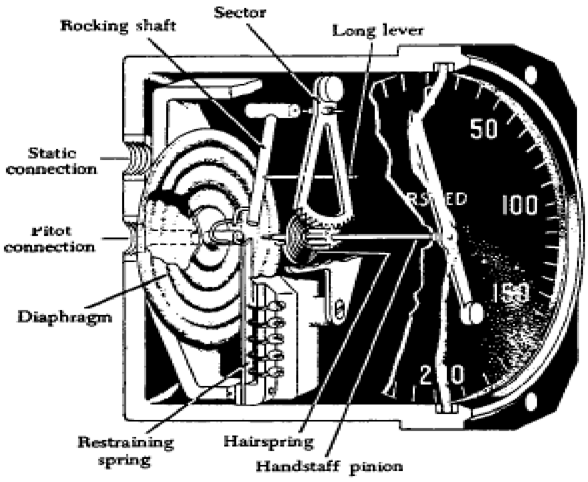
    Artificial horizon (also known as attitude indicates) is used to provide the pilot with an indication of the aircraft attitude in both pitch and roll.

14. What aircraft instruments are connected to the pitot-static system?
    - The altimeter,
    - vertical speed indicator,
    - airspeed, and
    - Mach meter in high performance jets

15. Name several of the indication errors that may be found in altimeters
    - Scale errors,
    - Hysteresis,

- Friction,
- Installation

16. What are two items that should be considered during inspection of a magnetic compass?
    - The fluid must be clea
    - The housing must be full with no bubbles
    - The card must be legible and the lubber line intact
    - The compass should be properly calibrated
17. Draw the diagram of an airspeed indicator



18. Differentiate indicated altitude and true altitude
    Indicated altitude—read directly from the altimeter (uncorrected) when it is set to the current altimeter setting.
    True altitude—the vertical distance of the aircraft above sea level—the actual altitude. It is often expressed as feet above mean sea level (MSL). Airport, terrain, and obstacle elevations on aeronautical charts are true altitudes.
19. What is the function of hydraulic pressure gauge?
    The mechanisms used in raising and lowering thelanding gear or flaps in most aircraft are operated by a hydraulic system. A pressure gage to measurethe differential pressure in the hydraulic system indicates how this system is functioning. Hydraulicpressure gages are designed to indicate either thepressure of the complete system or the pressure ofan individual unit in the system.
20. What is the limitation of gyro Compass?
    - It requires a constant source of electrical power. In case of any interruption in its operation for any length of time, nearly four hours may be required for it to settle back into reliable operation.
    - It requires intelligent care, attention and maintenance.
    - The accuracy decrease when latitudes above 75^o.

Dept. of Aeronautical Engineering

PART- B QUESTIONS

U20AE402 AIRCRAFT SYSTEMS AND INSTRUMENTS

Unit I

1. Explain the working of the typical hydraulic system used for the passenger aircraft.
2. Describe the working of shock absorber of the landing gear system.
3. Explain hydraulic system used in modern aircraft with neat sketch.
4. Draw a neat sketch of BOGIE truck main landing gear assembly and explain its operation.
5. Explain the advantages and disadvantages of a tail wheel and nose wheel landing gear system.
6. Explain the antiskid brake control system.
7. Describe the typical hydraulic system used for retaction of landing gear with a neat sketch.
8. Explain the following
   (a) Pressure regulators used in hydraulic system
   (b) Flow restrictors
9. Explain the following
   (a) Hydraulic brake system
   (b) Power boost brake system
10. Explain the following
    (a) Pneumatic system uses in aircrafts
    (b) Oleo – pneumatic struct
    (c) Pressure regulators
    (d) Sequencing circuit opeartion.

Unit II

1. Explain the working principles of power assisted and power actuated systems.
2. Explain the power assisted and flexible push pull rod control systems with neat sketches.
3. Explain the working principles of powered flight control systems.
4. Explain the following with neat sketches:
   (a) Engine Control Systems
   (b) Autopilot systems
5. Describe how fully powered flight control systems works.
6. Explain in detail about auto pilot system with a block diagram.
7. Explain the following
   (a) Autopilot system
   (b) Fly by wire system
   (c) Push pull rod system
8. Define autopilot.Explain the functions and working principles of autopilot with neatsketch
9. Explain the working principles of fly by wire flight control systems and its advantages and disadvantages.

10. Explain in detail about auto pilot system components with a block diagram

Unit III

1. Explain with a neat sketch how fuel system funtion for a piston engine.
2. Describe aircraft engine ignition system and starting system operation with neat sketches.
3. Explain with a neat sketch of typical fuel system used in jet engines.
4. Explain with neat sketches of the one of the starting systems for jet engines.
5. Explain the ignition and starting systems in reciprocating and jet engines.
6. Explain gas turbine engine fuel system and its components with a neat sketch.
7. What are the basic components present in the aircraft fuel system? Explain briefly about gravity feed fuel system.
8. Explain the working principles different type carburators used in piston engine.
9. Explain the working principles different type carburators used in jet engine
10. Explain briefly lubrication systems used in Jet engine.

Unit IV

1. Explain the working of the different fire detection and smoke detection techniques used in aircraft with neat sketches.
2. Draw the basic cycle of air cycle system and explain with neat sketch.
3. Explain the boost starp air cycle system with neat sketch.
4. Explain the operation of oxygen system with neat sketch.
5. Explain any one type of Deicing system with neat sketch.
6. What do you understand by antiicing and deicing problems in aircraft? Explain the system to control them.
7. With neat sketches, explain the evaporative vapour cycle and evaporative air cycle systems.
8. Explain cabin pressurization systems and its components.
9. What are the requirements of fire protection system? Explain briefly about the thermo couple and tubular heat detectors.
10. With a neat sketch, explain how fire and smoke detection systems works.

Unit V

1. Explain the working principles of gyroscopic instruments
2. Explain with neat sketch, construction and working of an Altimeter.
3. Explain in detail about the purpose and importance of various types of temperature gauges used at different location of the aircraft.
4. Explain the following
   (a) Altimeter
   (b) Mach meter
   (c) Airspeed indicator
   (d) Pressure gauge
5. Write shorte notes on
   (a) Artificial horizon
   (b) Turn and Bank indicator
   (c) Tachometer
   (d) HIS & ADI
6. Explain with neat sketch, construction and working of a Pitot tube
7. Explain with neat sketch, construction and working of an accelerometer
8. Explain with neat sketch, construction and working of a Mechanical Tachometer
9. Describe with neat sketch, construction and working of an altimeter and its advantages and disadvantages.
10. Explain the working principles of fuel flow indicator

UNIT-I

BASIC HYDRAULIC SYSTEM

Each hydraulicsystem has a minimum number of basiccomponents through whichthe fluid is transmitted.

Hand Pump System

1. **The reservoir**, stores the supply of hydraulic fluid for operation of the system.
2. It fill the system fluid when needed, provides room for thermal expansion, and in some systems provides a means for bleeding air from the system.
3. **A pump** is necessary to create a flow of fluid. The pump is hand operated.
4. However, aircraft systems aremostly equipped with engine-driven or electric motordrivenpumps.
5. **The selector valve** is used to direct the flow of fluid. These valves are normally actuated by solenoids

or manually operated, either directly or indirectlythrough use of mechanical linkage.

6. **An actuating cylinder** converts fluid pressure into useful work by linear or reciprocating mechanical motion, whereas a motor converts fluid pressure into useful work by rotary mechanical motion.
7. The flow of hydraulic fluid can be traced from the reservoir to the selector valve in figure 8-5.
8. With the selector valve in the position shown, the hydraulic fluid flows through the selector valve to the right-hand end of the actuating cylinder.
9. Fluid pressure then forces the piston to the left, and at the same time the fluidwhich is on the left side of the piston (figure 8-5) is forced out andback to the reservoir through the return line.
10. When the selector valve is moved to the oppositeposition, the fluid from the pump flows to the left side of the actuating cylinder, thus reversing the process.
11. Movement of the piston can be stopped at any time by moving the selector valve to neutral. In this position, all four ports are closed and pressure is trapped in both working lines.

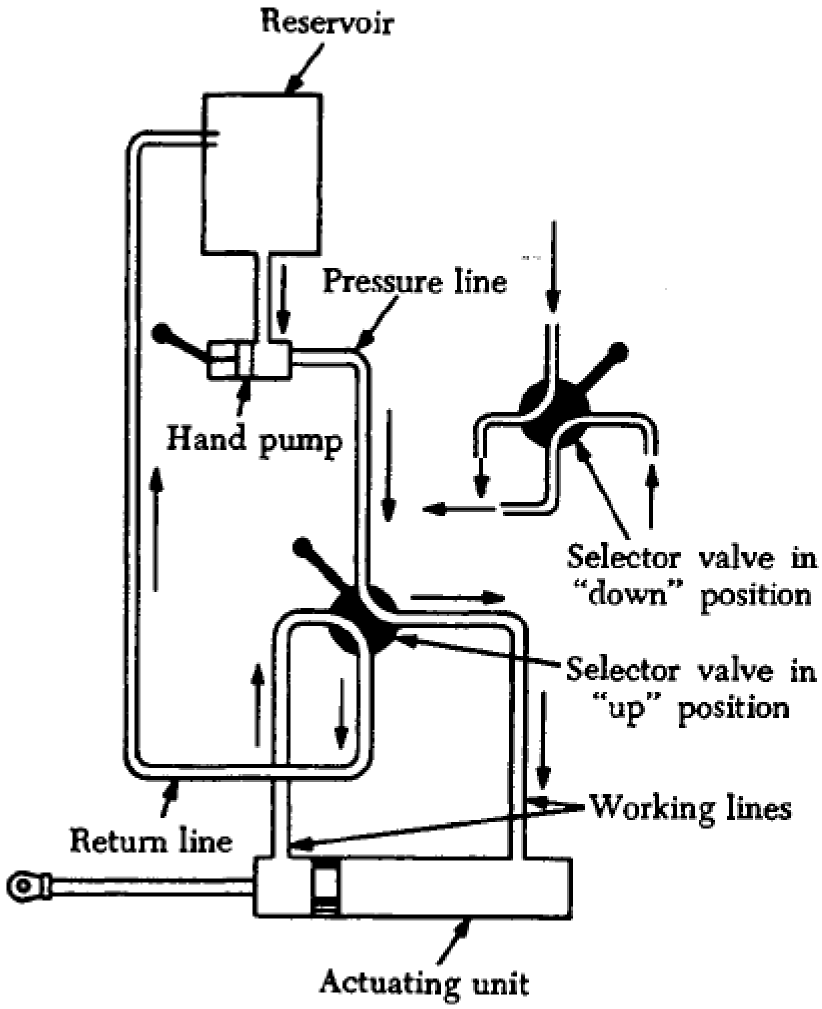


FIGURE 8–5. Basic hydraulic system with hand pump.

RESERVOIRS

There is a tendency to envision a reservoir as anindividual component; however, this is not always true. There are two types of reservoirs and theyare:

(l) In-Line-this type has its own housing, iscomplete within itself, and is connectedwith other components in a system by tubingor hose.

(2) Integral-this type has no housing of itsown but is merely a space set aside withinsome major component to hold a supply ofoperational fluid. A familiar example ofthis type is the reserve fluid space foundwithin most automobile brake master cylinders.

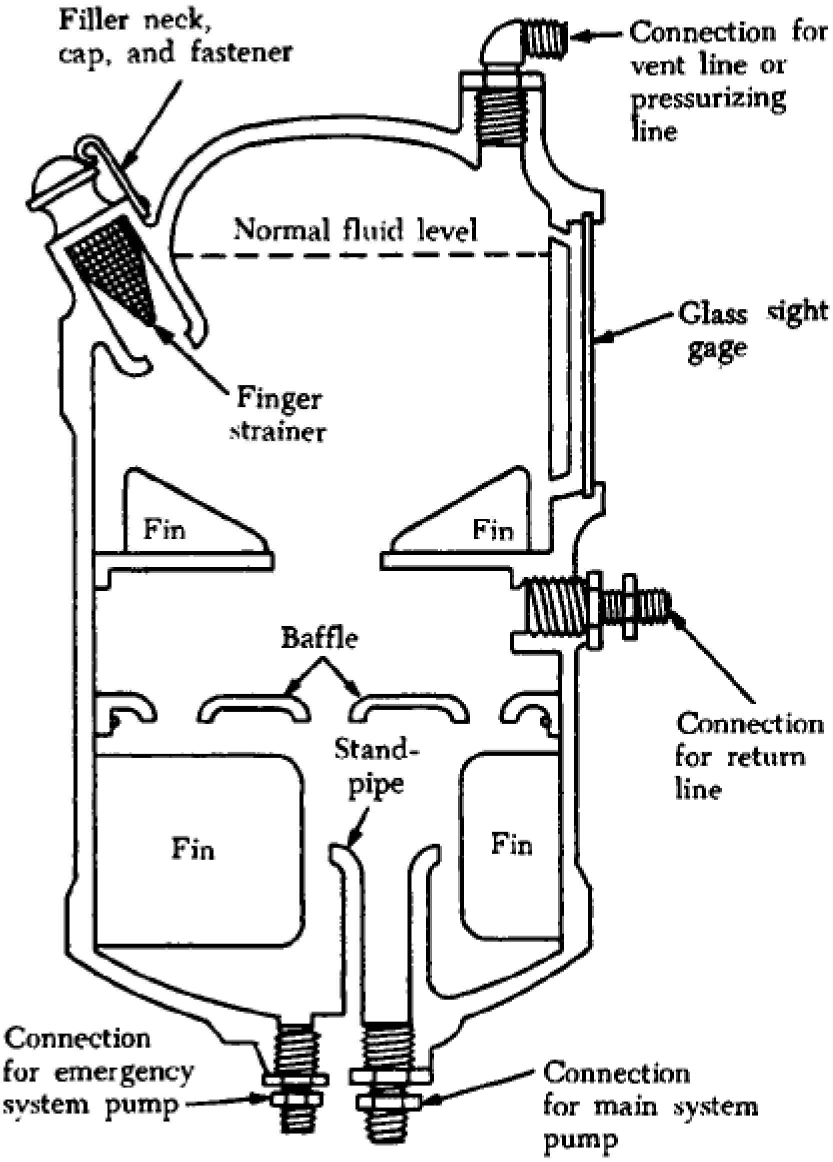


FIGURE 8–7. Reservoir, "in-line".

Power-Driven Pumps

Many of the power-driven hydraulic pumps ofcurrent aircraft are of variable-delivery, compensator-Controlled type. There are some constantdelivery pumps in use. Principles of operation arethe same for both types of pumps.

a. Constant-Delivery Pump

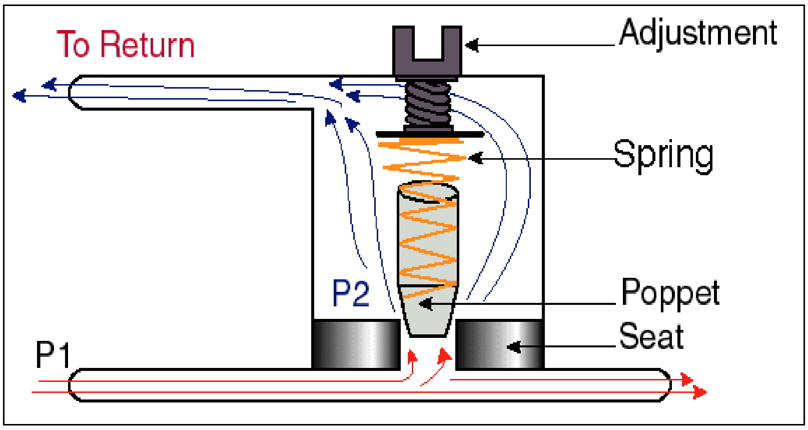
1. A constant-delivery pump, forces a fixed or unvarying quantity of fluidthrough the outlet port during each revolution ofthe pump.
2. Constant-delivery pumps are sometimescalled constant-volume or fixed-delivery pumps.
3. They deliver a fixed quantity of fluid per revolution,regardless of the pressure demands. Since theconstant-delivery pump provides a fixed quantity offluid during each revolution of the pump, the quantity of fluid delivered per minute will depend uponpump r.p.m.
4. When a constant-delivery pump is usedin a hydraulic system in which the pressure must bekept at a constant value, a pressure regulator isrequired.

b. Variable-Delivery Pump

1. A variable-delivery pump has a fluid output thatis varied to meet the pressure demands of the system
   by varying its fluid output.
2. The pump outputis changed automatically by a pump compensatorwithin the pump.

Pressure Relief Valves

1. A pressure relief valve is used to limit the amount of pressure being exerted on a confined liquid.
2. Thisis necessary to prevent failure of components or rupture of hydraulic lines under excessive pressures.
3. The pressure relief valve is a system safety valve.



4. The adjustment screw at the top of the pressure relief valve is set for a certain pressure value, let us call it P_2.
5. In general, even with a pressure of P_1, the poppet would lift up, except that the spring is strong and has downward force forcing the poppet closed.
6. Poppet will not move until a pressure greater than that required is felt by the system (i.e., $P_1 > P_2$).
7. When the pressure increases, the poppet will move up, forcing the excess liquid to move through opening at high velocity.
8. On other side of seat, pressure is zero because the back side of the relief valve is connected to the return line.
9. When the pressure in the system decreases below maximum, poppet will return to its seated position, sealing the orifice and allowing the fluid to follow its normal path.
10. This type of pressure relief valves are only made to be used intermittently.

Pressure Regulators

1. Pressureregulators are pressurized by constant-delivery type pumps.
2. One purpose of the pressure regulator is to manage the output ofthe pump to maintain system operating pressure within a predetermined range.
3. The other purpose isto permit the pump to turn without resistance (termed unloading the pump) at times when pressurein the system is within normal operating range.

Pressure Gage

1. The purpose of this gage is to measure the pressure,used to operate hydraulicunits on the aircraft.
2. The gage uses a Bourdon tube and a mechanical arrangement to transmit the tube expansion to the indicator on the face of the gage.
3. A vent in the bottom of the case maintains atmospheric pressure around the Bourdon tube. It also provides a drain for any accumulated moisture.

Accumulator

1. The accumulator is a steel sphere divided into two chambers by a synthetic rubber diaphragm.
2. The upper chamber contains fluid at system pressure, while the lower chamber is charged with air.

The function of an accumulator is to:

a. Dampen pressure surges in the hydraulicsystem caused by actuation of a unit and theeffort of the pump to maintain pressure at apreset level.

b. Aid or supplement the power pump whenseveral units are operating at once by supplyingextra power from its "accumulated"or stored power.

c. Store power for the limited operation of ahydraulic unit when the pump is not operating.

d. Supply fluid under pressure to compensatefor small internal or external (not desired)leaks which would cause the system to cyclecontinuously by action of the pressure switchescontinually "kicking in."

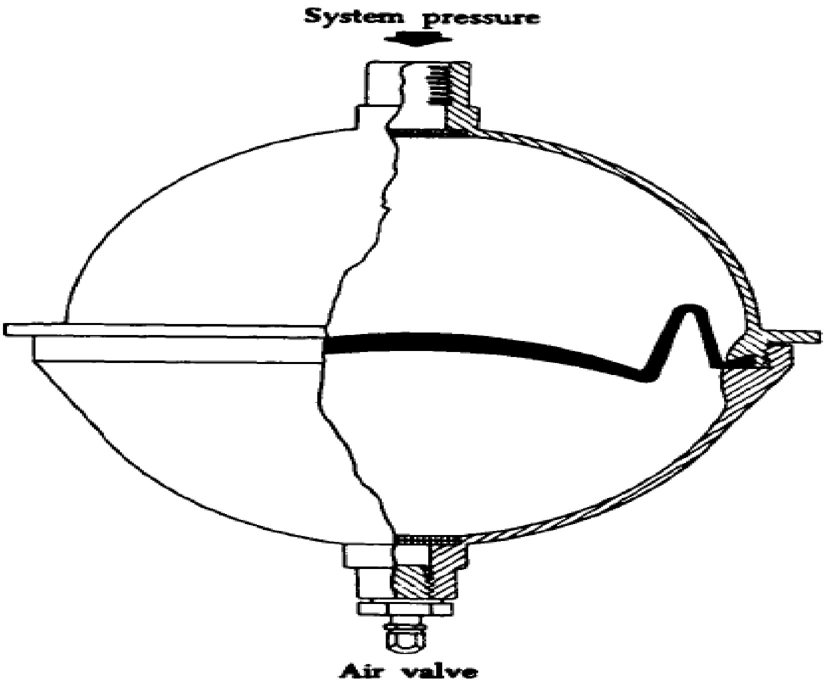


FIGURE 8–19. Diaphragm-type accumulator.

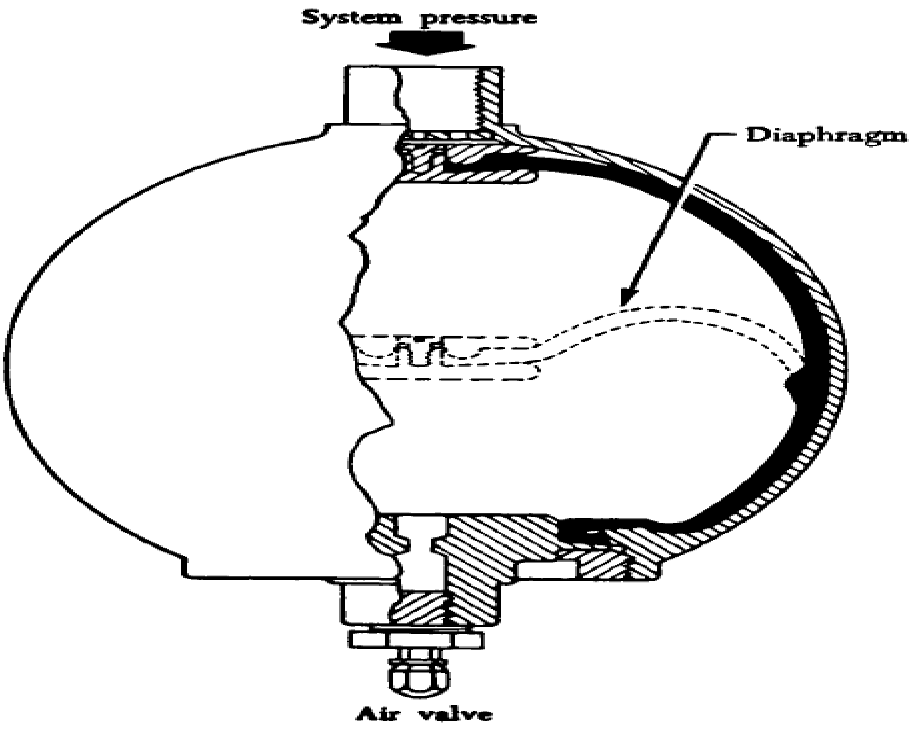
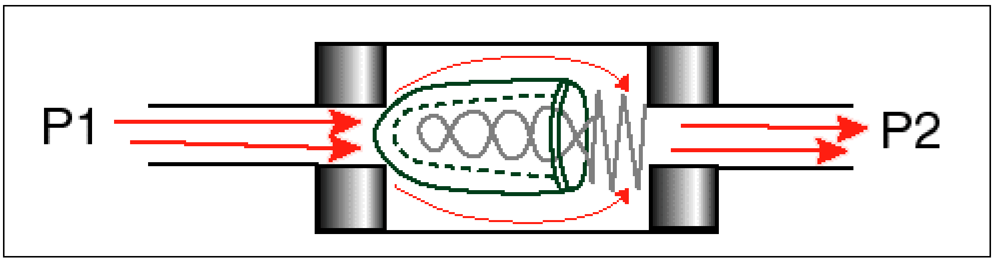


FIGURE 8–20. Bladder-type accumulator.

Function of Check Valves

Check Valves are hydraulic devices which permit flow of fluid in one direction only.

Check Valve Used In Aircrafts



1. Poppet type valve is the preferred type that is used in hydraulics now. The front of the poppet (left side of the picture above) sits tightly on the hard seat (darker shaded areas on the left side). The poppet works on the following principle.
2. When high pressure fluid (with pressure P_1) comes in on the left, it forces the poppet open. Since $P_1>P_2$, the force on the left side of the poppet (F_1) is greater than the force due to the spring (F_2) and is just enough to open the poppet.
3. But, when flow stops, or there is a high pressure flow from the right side of the poppet, then $P_2>P_1$ and the pressure forces the poppet against the valve seat, closing off the opening. Thus the fluid is allowed to flow through in one direction only.

4. Check valves are designed so as not to tolerate leakage. The purpose of the light spring is only to keep the poppet on the seat.

ACTUATING CYLINDERS

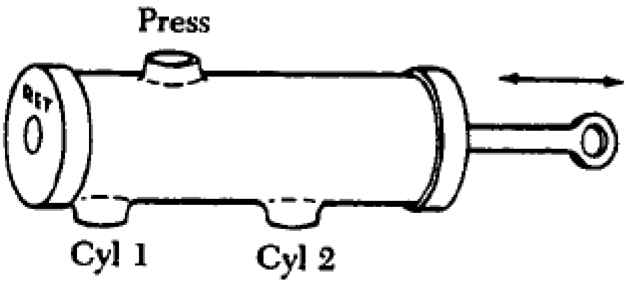
1. An actuating cylinder transforms energy in theform of fluid pressure into mechanical force, oraction, to perform work.
2. Actuating cylinders are of two major types:(l) Single-action and (2) Double-action.

Single-Action Actuating Cylinder

3. Fluid under pressure enters theport at the left and pushes against the face of thepiston, forcing the piston to the right.
4. As thepiston moves, air is forced out of the spring chamberthrough the vent hole, compressing the spring.When pressure on the fluid is released to the pointthat it exerts less force than is present in the compressedspring, the spring pushes the piston towardthe left.
5. As the piston moves to the left, fluid isforced out of the fluid port. At the same time, themoving piston pulls air into the spring chamberthrough the venthole.
6. A three-way control valveis normally used for controlling the operation of asingle-action actuating cylinder.

SELECTOR VALVES

1. Selector valves are used to control the directionof movement of an actuating unit.
2. A selectorvalve provides a pathway for the simultaneous flowof hydraulic fluid into and out of a connectedactuating unit.
3. One port of the typical selector valve is connectedwith a system pressure line for the input of fluid pressure.
4. A second port of the valve is connected toa system return line for the return of fluid to the reservoir.
5. The ports of an actuating unit throughwhich fluid enters and leaves the actuating unit are connected by lines to other ports of the selectorvalve.
6. Selector valves have various numbers of ports. Selector valves having four ports are the most commonly used.



Typical port markings on selector valve having slide movement

FIGURE 8–28. Typical port markings on selector valves.

AIRCRAFT PNEUMATIC SYSTEMS

1. Some aircraft manufacturers equip their aircraft with a pneumatic system. Such systems operated by air instead of a liquid for transmitting power.

   Pneumatic systems are sometimes used for:

   (1) Brakes.

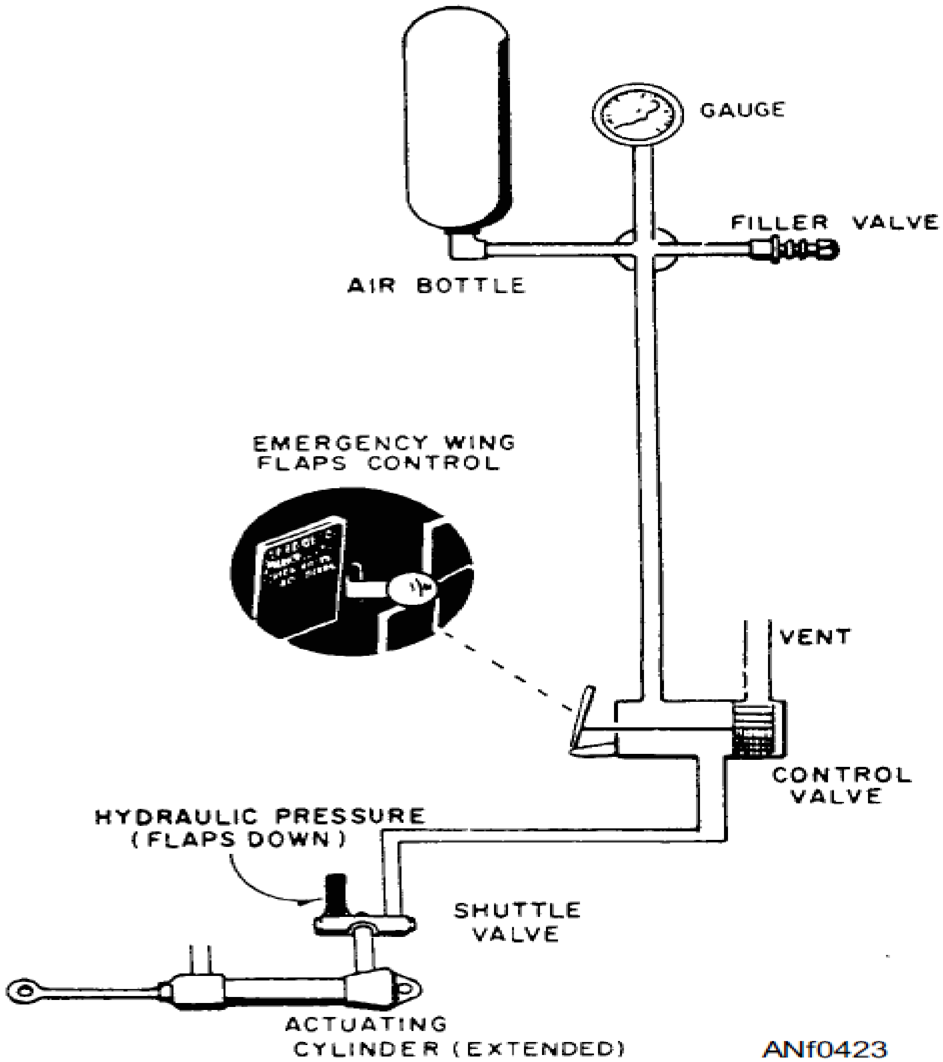
   (2) Opening and closing doors.

   (3) Driving hydraulic pumps, alternators,starters, water injection pumps, etc.

   (4) Operating emergency devices.

Working Principle:

2. There are two types of pneumatic systems currentlyused in naval aircraft. One type uses storage bottles foran air source, and the other has its own air compressor.Generally, the storage bottle system is used only foremergency operation.
3. **Air storagecylinder** pneumatic systems are in use for emergencybrakes, emergency landing gear extension, emergencyflap extension, and for canopy release mechanisms.
4. **When the control valve** is properly positioned, thecompressed air in the storage bottle is routed throughthe shuttle valve to the actuating cylinder.
5. **The shuttle valve** is a pressure-operatedvalve that separates the normal hydraulic system from the emergency pneumatic system.
6. **When the controlhandle** is returned to the normal position, the airpressure in the lines is vented overboard through thevent port of the control valve.
7. The other type of pneumatic system in use has itsown air compressor. It also has other equipmentnecessary to maintain an adequate supply ofcompressed air during flight.
8. Most systems of this typemust be serviced on the ground prior to flight.
9. The air compressor used in most aircraft is driven by ahydraulic motor.
10. Aircraft that have an air compressoruse the compressed air for normal and emergencysystem operation.



Type's pneumatic system

a. **High Pressure System**

1. For high-pressure systems, air is usually stored in metal bottles (figure 8-31) at pressures ranging from 1,000 to 3,000 p.s.i., depending on the particularsystem.
2. This type of air bottle has two valves,one of which is a charging valve. A ground-operated compressor can be connected to this valve toadd air to the bottle.
3. The other valve is a control valve. It acts as a shutoff valve, keeping air trappedinside the bottle until the system is operated.
4. Instead, the supply of bottled air is reserved for emergency operation of such systems as the landing gear or brakes. The usefulness of this type of system is increased, however,if other air-pressurizing units are added to the aircraft.
5. On some aircraft, permanently installed air compressors have been added to re-charge air bottles whenever pressure is used for operating a unit.Several types of compressors are used for this purpose.

Advantage:

4. Storage cylinder is light in weight.

Disadvantage

1. The system cannot be re-charged during flight,
5. Operation is limited by the small supply of bottled air.

6. Such an arrangement cannot be used for the continuous operation of a system

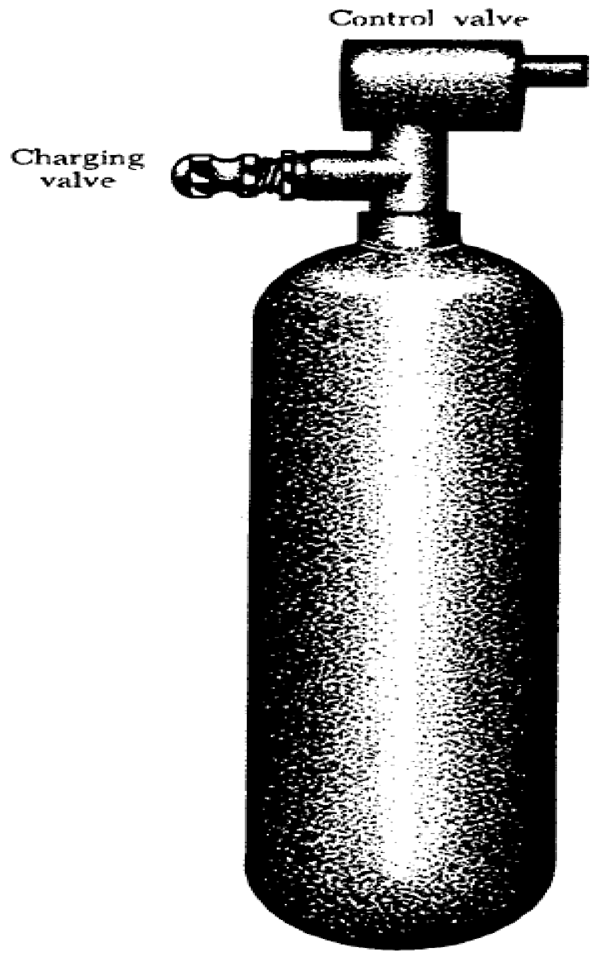


FIGURE 8–31. Steel cylinder for high-pressure air

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b. Medium Pressure System

1. A medium-pressure pneumatic system (100 - 150 p.s.i.) usually does not include an air bottle. Instead, it generally draws air from a jet engine compressor section.
2. In this case, air leaves the engine through a takeoff and flows into tubing, carrying air first to the pressure-controlling units and then to the operating units.

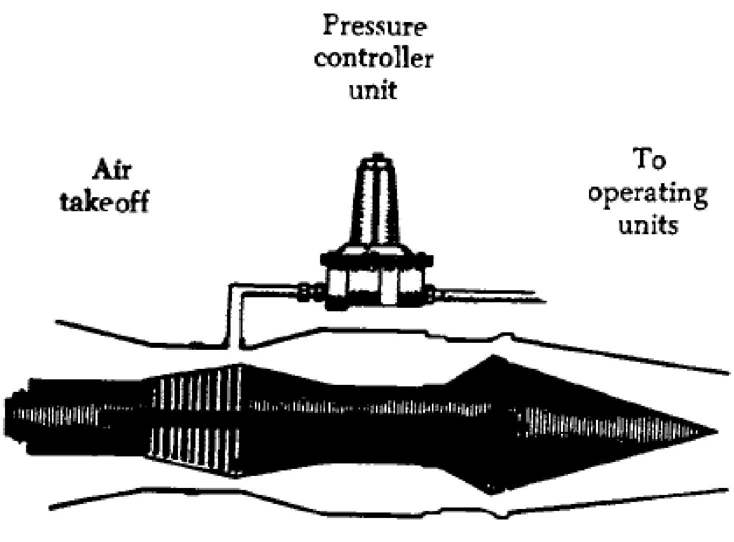


FIGURE 8–33. Jet engine compressor with pneumatic system takeoff.

c. Low Pressure System

1. Many aircraft equipped with reciprocating enginesobtain a supply of low-pressure air fromvane-type pumps. These pumps are driven by electricmotors or by the aircraft engine.
2. Figure 8-34shows a schematic view of one of these pumps,which consists of a housing with two ports,a drive shaft, and two vanes.
3. The drive shaft andthe vanes contain slots so the vanes can slide backand forth through the drive shaft.
4. The shaft iseccentrically mounted ·in the housing, causing thevanes to form four different sizes of chambers (A,B, C, and D). In the position shown, B is thelargest chamber and is connected to the supply port.As depicted in the illustration, outside air can enterchamber B of the pump.
5. When the pump begins to operate, the drive shaft rotates and changes positions of the vanes and sizes
   of the chambers. Vane No. 1 then moves to the right (figure 8-34), separating chamber B from the supply port.
6. Chamber B now contains trapped air. As the shaft continues to turn, chamber B moves downward and becomes increasingly smaller, gradually compressing its air.
7. Near the bottom of the pump, chamber B connects to the pressure port and sends compressed air into the pressure line. Then chamber B moves upward again becoming increasingly larger in area.
8. At the supply port it receives another supply of air. There are four such chambers in this pump, and each goes through this same cycle of operation. Thus, the pump delivers to the pneumatic system a continuous supply of compressed air at from 1 to 10 p.s.i.

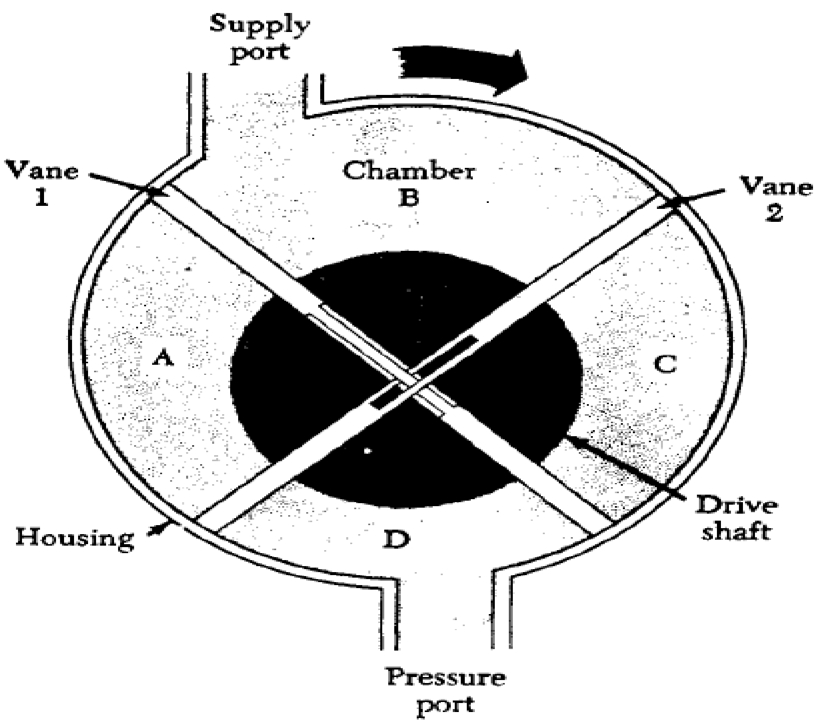


FIGURE 8–34. Schematic of vane-type air pump.

PNEUMATIC SYSTEM COMPONENTS

Pneumatic systems are often compared to hydraulic systems, but such comparisons can onlyhold true in general terms. Pneumatic systems donot utilize reservoirs, hand pumps, accumulators,regulators, or engine-driven or electrically-drivenpower pumps for building normal pressure.

Relief Valves

1. Relief valves are used in pneumatic systems to prevent damage.
2. They act as pressure-limiting unitsand prevent excessive pressures from bursting lines and blowing out seals.
3. At normal pressures, a spring holds the valve closed (figure 8-35), and air remains in the pressure line.
4. If pressure grows too high, the force it creates on the disk overcomes spring tension andopens the relief valve.
5. Then, excess air flows through the valve and is exhausted as surplus airinto the atmosphere.
6. The valve remains open until the pressure drops to normal.

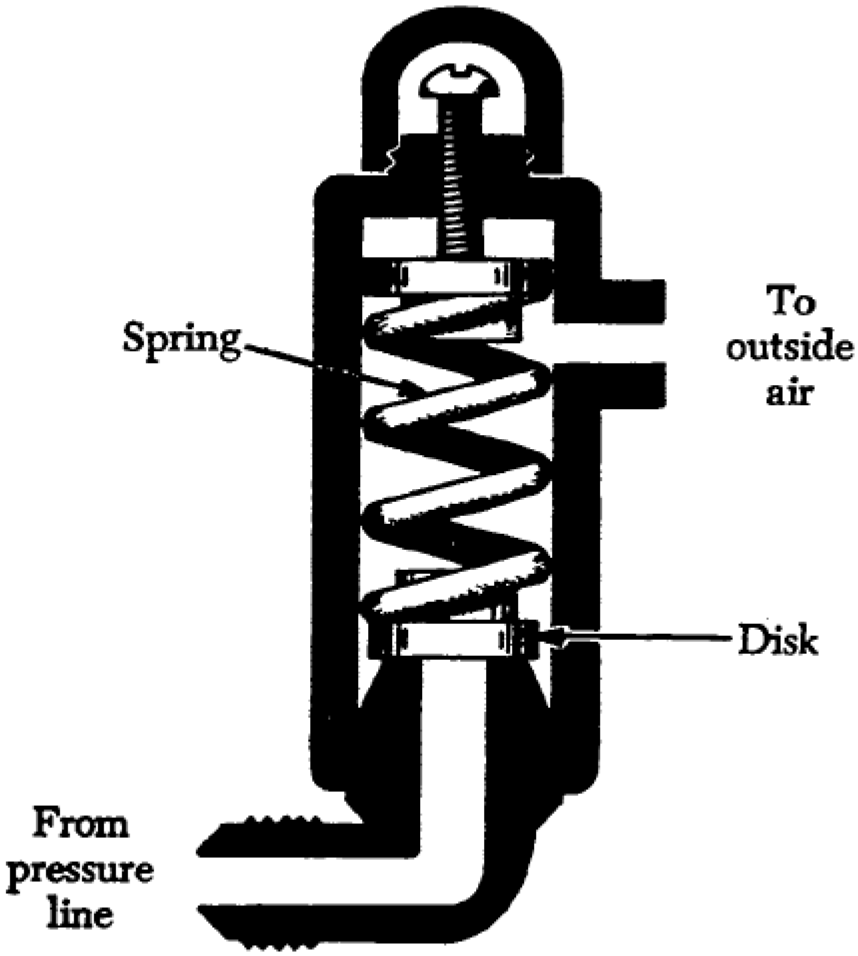


FIGURE 8–35. Pneumatic system relief valve.

Check Valves

1. Check valves are used in both hydraulic and pneumatic systems.
2. Air enters the left port of the check valve, compresses a light spring, forcingthe check valve open and allowing air to flow out the right port.

3. But if air enters from the right,air pressure closes the valve, preventing a flow of air out the left port.
4. Thus, a pneumatic check valveis a one-direction flow control valve.

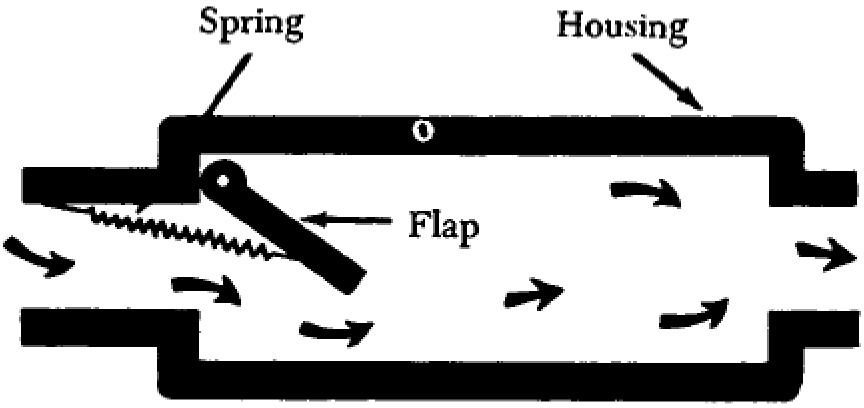


FIGURE 8–37. Pneumatic system check valve.

Restrictors

1. Restrictors are a type of control valve used in pneumatic systems.
2. An orifice type restrictor with a large inlet port and a small outlet port.
3. The small outlet port reduces the rate of airflow and the speed of operation of an actuating unit.

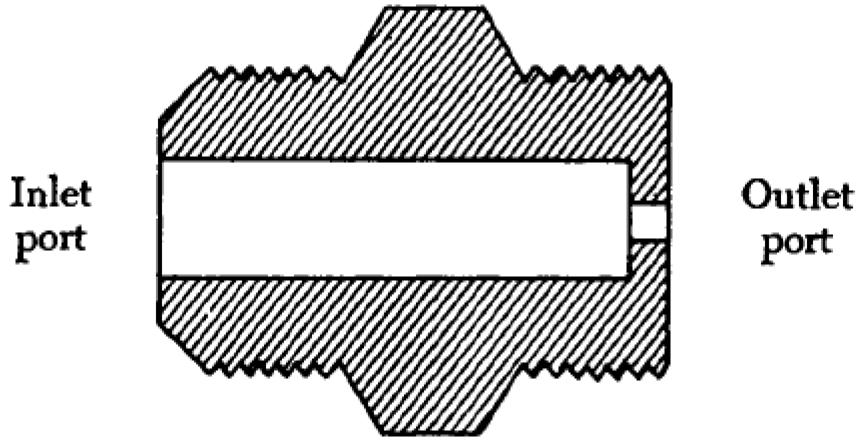


FIGURE 8–38. Orifice restrictor.

Variable Restrictor

1. Another type of speed-regulating unit is the variable restrictor shown in figure 8-39.
2. It contains anadjustable needle valve, which has threads around the top and a point on the lower end.
3. Depending onthe direction turned, the needle valve moves the sharp point either into or out of a small opening todecrease or increase the size of the opening.
4. Since air entering the inlet port must pass through thisopening before reaching the outlet port, this adjustment also determines the rate of airflow through therestrictor.

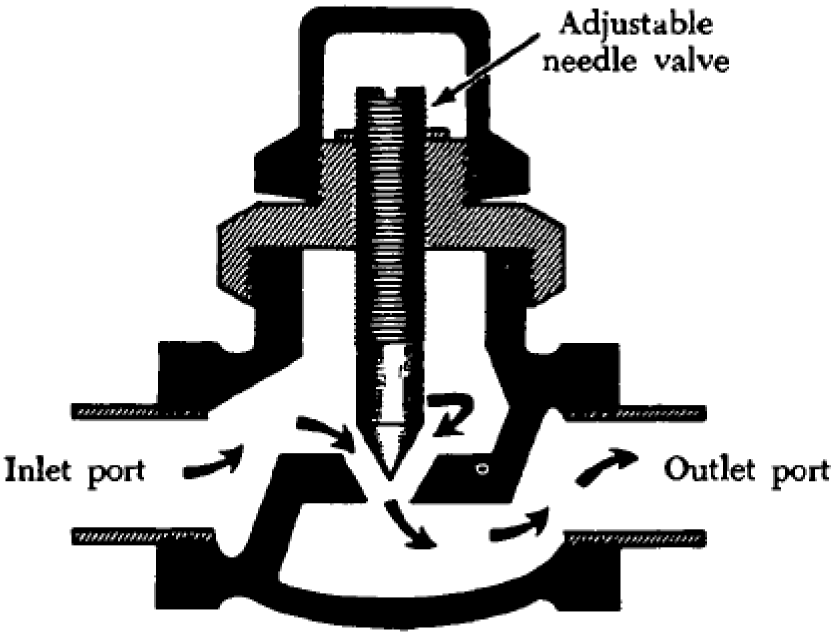


FIGURE 8–39. Variable pneumatic restrictor.

Filters

1. Pneumatic systems are protected against dirt by various types of filters. A micronic filter consists of a housing with two ports,a replaceable cartridge, and a relief valve.
2. Normally, air enters the inlet, circulates around the cellulose cartridge, then flows to the center of the cartridge and out the outlet port.
3. If the cartridge becomes clogged with dirt, pressure forces the relief valve open and allows unfiltered air to flow out the outlet port.

Air Bottle

1. The air bottle usually stores enough compressed air for several applications of the brakes.
2. A high pressureair line connects the bottle to an air valve which controls operation of the emergency brakes.
3. If the normal brake system fails, place the control handle for the air valve in the "on" position.
4. The valve then directs high-pressure air into lines leading to the brake assemblies. But before air enters the brake assemblies, it must first flow through a shuttle valve.

TYPICAL PNEUMATIC POWER SYSTEM

1. A typical turbine-engine pneumatic power system supplies compressed air for various normal and emergency actuating systems.
2. The compressed air is stored in storage cylinders in the actuating systemsuntil required by actuation of the system.
3. These cylinders and the power system manifold are initially charged with compressed air or nitrogen from an external source through a single air-charge valve.

4. In flight, the air compressor replaces the air pressure and volume lost through leakage, thermal contraction, and actuating system operation.
5. The compressor inlet air is filtered through ahigh-temperature, 10-micron filter and the air pressure is regulated by an absolute pressure regulator to provide a stabilized source of air for the compressor.
6. The air compressor hydraulic actuatingsystem consists of a solenoid-operated selectorvalve, flow regulator, hydraulic motor, and motorbypass (case drain) line check valve.
7. When energized,the selector valve allows the system to bepressurized to run the hydraulic motor; when deenergizedthe valve blocks off utility system pressure,stopping the motor.
8. **The flow regulator**, compensating for the varying hydraulic system flow andpressures, meters the flow of fluid to the hydraulicmotor to prevent excessive speed variation and/oroverspeeding of the compressor.
9. **A check valve** inthe motor bypassline prevents system return linepressures from entering the motor and stalling it.The air compressor is the pneumatic system'spressurizing air source.
10. **The compressor** is activatedor deactivated by the manifold pressure-sensingswitch, which is an integral part of the moistureseparator assembly.
11. **The moisture separator assembly** is the pneumaticsystem's pressure-sensing regulator and relief valve.
12. **The manifold (system) pressure switch** governs theoperation of the air compressor. When the manifoldpressure drops below 2, 750 p.s.i., the pressure-sensingswitch closes, energizing the separator's moisturedump valve and the hydraulic selector valvewhich activates the air compressor.
13. When the **manifoldpressure** builds up to 3,150 p.s.i., the pressuresensingswitch opens, de-energizing the hydraulicselector valve to deactivate the air compressor anddump valve, thus venting overboard any moistureaccumulated in the separator.
14. **The safety fitting**, installed at the inlet port of themoisture separator, protects the separator from internalexplosions caused by hot carbon particles orflames that may be emitted from the air compressor.
15. **A chemical drier** further reduces the moisturecontent of the air emerging from the moisture separator.
16. **A pressure transmitter** senses and electricallytransmits a signal to the pneumatic pressureindicator located in the cockpit. The indicating systemis an "autosyn" type that functions exactly likethe hydraulic indicating systems.
17. **An air-charge valve** provides the entire pneumaticsystem with a single external ground servicingpoint.
18. **An air pressure gage**, located near theair-charge valve, is used in servicing the pneumaticsystem. This gage indicates the manifold pressure.
19. **An air filter** (10-micron element) in the groundair-charge line prevents the entry of particle impurities into the system from the ground servicingsource.

Components

- **The pressure switch controls** system pressurization by sensing the system pressure between the check valve and the relief valve. It electrically energizesthe air compressor solenoid-operated selectorvalve when the system pressure drops below 2,750p.s.i., and de-energizes the selector valve when thesystem pressure reaches 3,100 p.s.i.

- **The condensation dump valve** solenoid is energized and depressurized by the pressure switch. When energized, it prevents the air compressor from dumping air overboard; when de-energized, it completely purges the separator's reservoir and lines up to the air compressor.
- **The filter** protects the dump valve port from becomingclogged and thus ensures proper sealing of the passage between the reservoir and the dumpport.
- **The check valve** protects the system against pressureloss during the dumping cycle and prevents backflow through the separator to the air compressorduring the relief condition.
- **The relief valve** protects the system against overpressurization(thermal expansion) . The relief valve
  opens when the system pressure reaches 3, 750 p.s.i.and re-seats at 3,250 p.s.i.
- **The thermostatically controlled wraparound-blankettype heating element** prevents freezing of themoisture within the reservoir due to low-temperature atmospheric conditions. The thermostat closesat 40° F. and opens at 60° F.

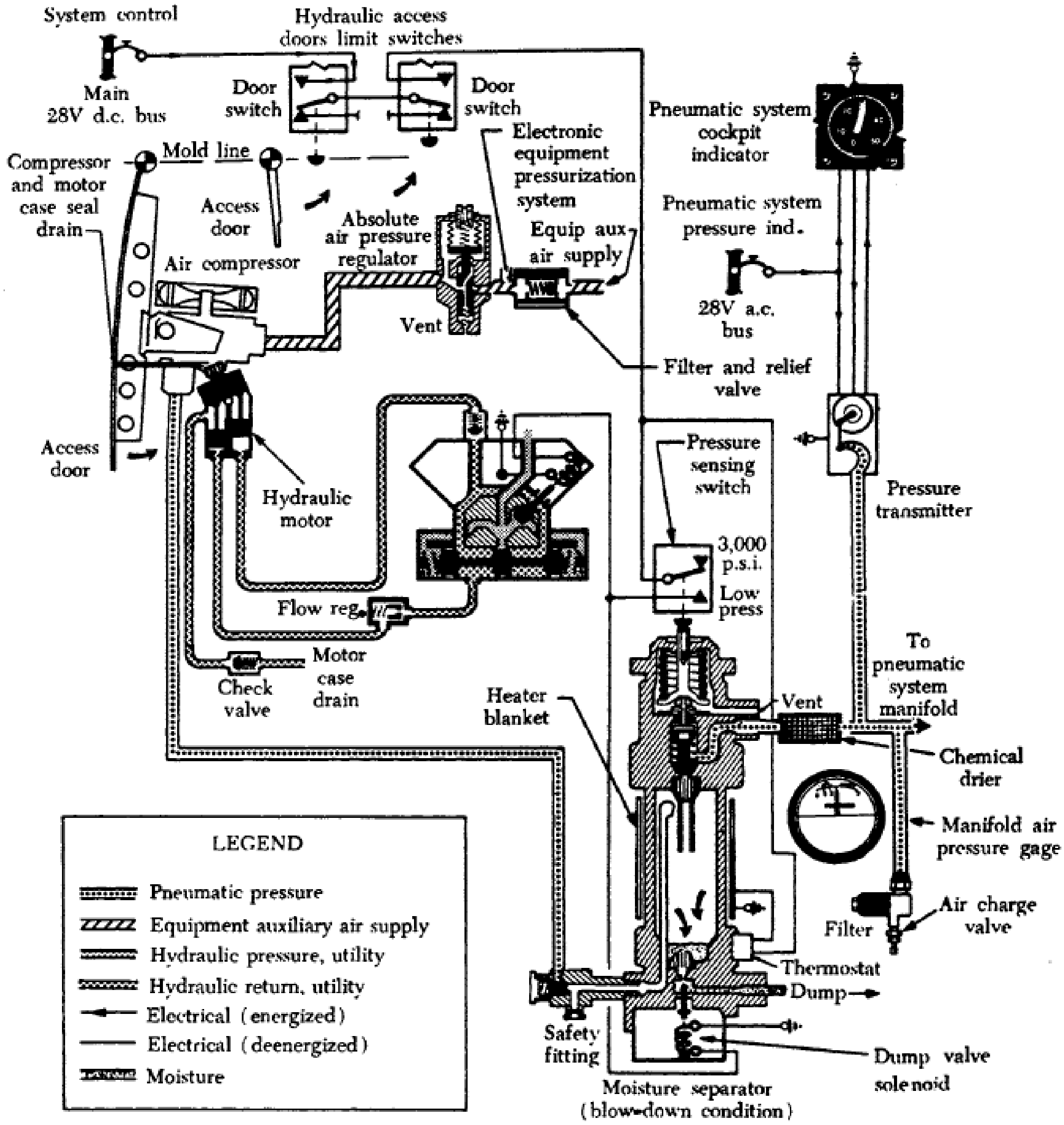


FIGURE 8–43. Pneumatic power system.

BRAKE SYSTEMS

1. Proper functioning of the brakes is of utmostimportance on aircraft. The brakes are used for slowing, stopping, holding, or steering the aircraft They must develop sufficient force to stop the aircraftin a reasonable distance; brakes must hold theaircraft for normal engine turn up; and brakes mustpermit steering of the aircraft on the ground.
2. Brakes are installed in each main landing wheel andthey may be actuated independently of each other.
3. The right-hand landing wheel is controlled byapplying toe pressure to the right rudder pedal and the left-hand wheel is controlled by the left rudderpedal.
4. Three types of brake systems are in general use:

(1) Independent systems, (2) power control systems,and (3) power boost systems. In addition, there are several different types of brake assembliesin widespread use.

a. Independent Brake Systems

1. In general, the independent brake system is used on small aircraft. This type of brake system is termed "independent" because it has its own reservoir and is entirely independent of the aircraft's main hydraulic system.
2. Independent brake systems are powered by mastercylinders similar to those used in the conventional automobile brake system.
3. **The system is composed**of a reservoir, one or two master cylinders, mechanical link,ge which connects each master cylinderwith its corresponding brake pedal, connectingfluid lines, and a brake assembly in each mainlanding gear wheel (figure 9-25).
4. **Each master cylinder** is actuated by toe pressureon its related pedal. The master cylinder builds up
   pressure by the movement of a piston inside asealed, fluid-filled cylinder.
5. The resulting hydraulicpressure is transmitted to the fluid line connected tothe brake assembly in the wheel. This results in thefriction necessary to stop the wheel.
6. **When the brake pedal** is released, the mastercylinder piston is returned to the "off" position bya return spring. Fluid that was moved into thebrake assembly is then pushed back to the mastercylinder by a piston in the brake assembly.
7. Thebrake assembly piston is returned to the "off" positionby a return spring in the brake. Some lightaircraft are equipped with a single master cylinderwhich is hand-lever operated and applies brakeaction to both main wheels simultaneously. Steeringon this system is accomplished by nosewheel linkage.
8. The typical master cylinder has a compensatingport or valve that permits fluid to flow from thebrake chamber back to the reservoir when excessivepressure is developed in the brake line due to temperaturechanges. This ensures that the master cylinderwon't lock or cause the brakes to drag.

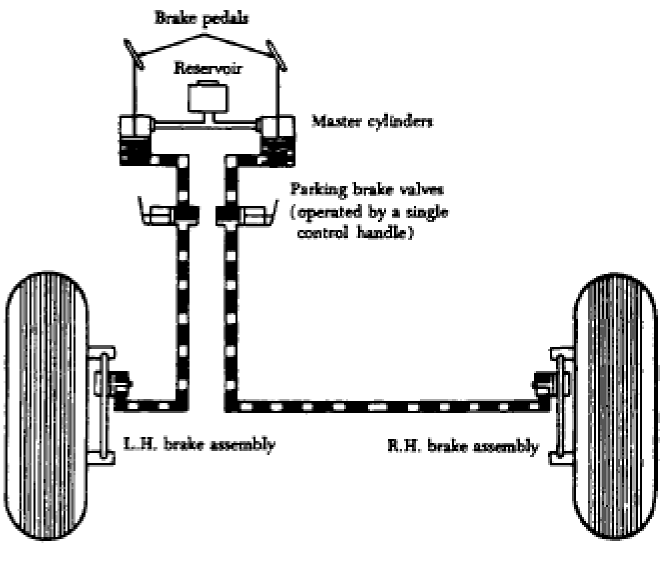


FIGURE 9–25. Typical independent brake system.

b. Power Brake Control Systems

c.

1. Power brake control valve systems (figure 9-28) are used on aircraft requiring a large volume of fluid to operate the brakes. As a general rule, thisapplies to many large aircraft. Because of theirweight and size, large wheels and brakes are required.
2. Larger brakes mean greater fluid displacementand higher pressures, and for this reason independent master cylinder systems are not practicalon heavy aircraft.
3. **In this system a line** is tapped off from the main hydraulic system pressure line. **The first unit** in this
   line is a check valve which prevents loss of brakesystem pressure in case of main system failure.
4. **The next unit** is the accumulator which stores a reserve supply of fluid under pressure. When the brakes are applied and pressure drops in the accumulator,more fluid enters from the main system and is trapped by the check valve.
5. **The accumulator** also acts as a surge chamber for excessive loadsimposed upon the brake hydraulic system. Following the accumulator are the pilot's and copilot's control valves.
6. **The control valves** regulate and control the volume and pressure of the fluid which actuates the brakes.
7. **Four check valves** and two orifice check valves are installed in the pilot's and copilot's brake actuati~ lines. The check valves allow the flow offluid in one direction only.
8. The **orifice check valves**allow unrestricted flow of fluid in one direction from the pilot's brake control valve; flow in theopposite direction is restricted by an orifice in the poppet. Orifice check valves help prevent chatter.
9. **The next unit** in the brake actuating lines is the pressure relief valve. In this particular system, the pressure relief valve is preset to open at 825 p.s.i. todischarge fluid into the return line, and closes

at

   760 s.i. minimum.
10. Each brake actuating line incorporates a shuttle valve for the purpose of isolating the emergency brake system from the normal brake system. When brake actuating pressure enters the shuttle valve, the shuttle is automatically moved to the opposite end of the valve.
11. This closes of the hydraulicbrake system actuating line. Fluid returning from the brakes travels back into the system to which theshuttle was last open.

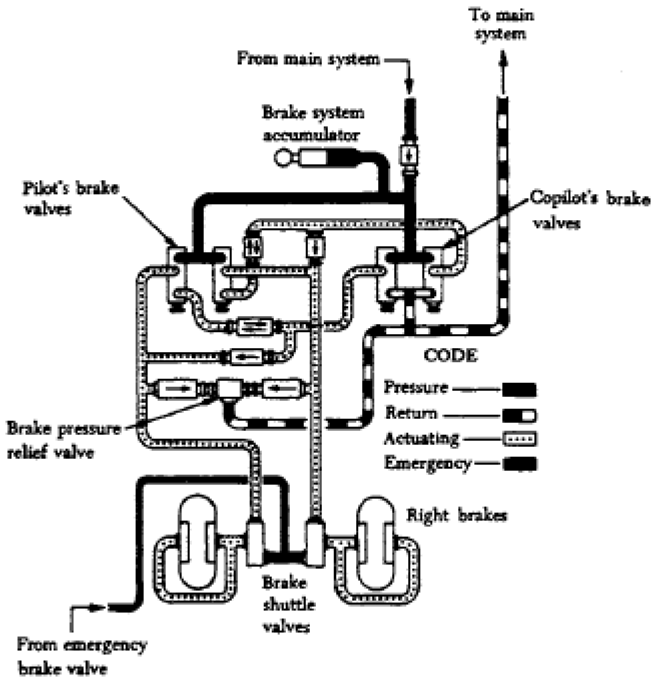
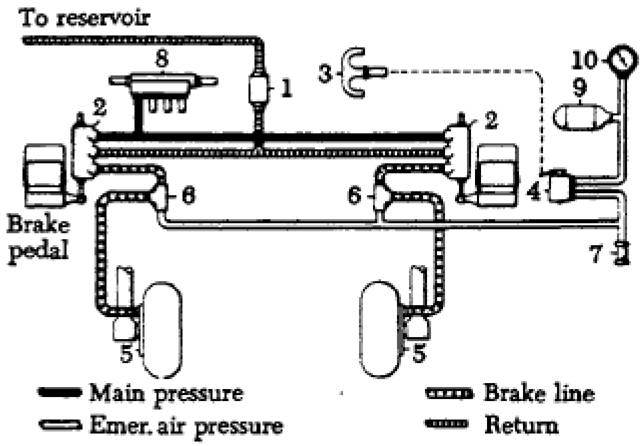


FIGURE 9–28. Typical power brake control valve system.

d. Power Boost Brake Systems

1. As a general rule, power boost brake systems areused on aircraft that land too fast to employ the independent brake system, but are too light inweight to require power brake control valves.
2. **In this type of system**, a line is tapped oft themain hydraulic system pressure line, but main hydraulicsystem pressure does not enter the brakes.
3. Main system pressure is used only to assist thepedals through the use of power boost master cylinders.
4. **A typical power boost brake system (figure9-32) consists** of a reservoir, two power boost master cylinders, two shuttle valves, and the brake assembly in each main landing wheel.
5. **A compressedair bottle** with a gage and release valve is installedfor emergency operation of the brakes. Main hydraulicsystem pressure is routed from the pressuremanifold to the power master cylinders.
6. **When thebrake pedals are depressed**, fluid for actuating thebrakes is routed from the power boost master cylindersthrough the shuttle valves to the brakes.
7. **When the brake pedals are released**, the mainsystem pressure port in the master cylinder is closed. Fluid that was moved into the brake assembly is forced out the return port by a piston in the brake assembly, through the return line to the brakereservoir.
8. The brake reservoir is connected to themain hydraulic system reservoir to assure an adequatesupply of fluid to operate the brakes.



1. Brake reservoir
2. Power boost master cylinder
3. Emergency brake control
4. Air release valve
5. Wheel brake
6. Shuttle valve
7. Air vent
8. Main system pressure manifold
9. Emergency air bottle
10. Emergency air gage

FIGURE 9–32. Power boost master cylinder brake system.

Aircraft Landing Gear Systems

Three basic arrangements of landing gear are used:

A. Tail wheel type landing gear (also known as conventional gear)

6. Tail wheel-type landing gear is also known as conventional gear because many earlyaircraft use this type of arrangement.
7. The main gear are located forward of the center of gravity, causing the tail to require support from a third wheel assembly.
8. A few early aircraft designs use a skid rather than a tail wheel.
9. This helps slow the aircraft upon landing and provides directional stability.
10. The resulting angle of the aircraft fuselage, when fitted with conventional gear, allows the use of a long propeller that compensates for older, underpowered engine design.
11. The increased clearance of the forward fuselage offered by tail wheel-type landing gear is also advantageous when operating in and out of non-paved runways.

Tandem landing gear

1. Few aircraft are designed with tandem landing gear.
2. As the name implies, this type of landing gear has the main gear and tail gear aligned on the longitudinal axis of the aircraft.
3. Sailplanes commonly use tandem gear, although many only have one actual gear forward on the fuselage with a skid under the tail.
4. The VTOL Harrier has tandem gear but uses small outrigger gear under the wings for support.

12. **Tricycle-type landing gear**

The most commonly used landing gear arrangement is the tricycle-type landing gear. It is comprised of main gear and nose gear.

Tricycle-type landing gear is used on large and small aircraft with the following benefits:

6. Allows more forceful application of the brakes without nosing over when braking, which enables higher landing speeds.
7. Provides better visibility from the flight deck, especially during landing and ground maneuvering.
8. The nose gear of a few aircraft with tricycle-type landing gear is not controllable. It simply casters as steering is accomplished with differential braking during taxi.
9. However, nearly all aircraft have steerable nose gear. On light aircraft, the nose gearis directed through mechanical linkage to the rudder pedals.
10. Heavy aircraft typically utilize hydraulic power to steer the nose gear.

Fixed and Retractable Landing Gear

Fixed Gear:

1. Further classification of aircraft landing gear can be made into two categories: fixed and retractable.

2. Many small, single engine light aircraft have fixed landing gear. This means the gear is attached to the airframe and remains exposed to the slipstream as the aircraft is flown.

3. As the speed of an aircraft increases, so does parasite drag. Mechanisms to retract and stow the landing gear to eliminate parasite drag add weight to the aircraft.

4. On slow aircraft, the penalty of this added weight is not overcome by the reduction of drag, so fixed gear is used.

5. As the speed of the aircraft increases, the drag caused by the landing gear becomes greater and a means to retract the gear to eliminate parasite drag is required, despite the weight of the mechanism.

6. A great deal of the parasite drag caused by light aircraft landing gear can be reduced by building gear as aerodynamically as possible and by adding fairings or wheel pants to streamline the airflow past the protruding assemblies.

7. A small, smooth profile to the oncoming wind greatly reduces landing gear parasite drag.

Retractable Gear:

1. Retractable landing gear stow in fuselage or wing compartments while in flight.

2. Once in these wheel wells, gear are out of the slipstream and do not cause parasite drag.

3. Most retractable gear have a close fitting panel attached to them that fairs with the aircraft skin when the gear is fully retracted.

4. *Other aircraft have separate doors* that open, allowing the gear to enter or leave, and then close again.


Shock Absorbing and Non-Shock Absorbing Landing Gear

1. In addition to supporting the aircraft for taxi, the forces of impact on an aircraft during landing must be controlled by the landing gear.

2. This is done in two ways:

    1) The shock energy is altered and transferred throughout the airframe at a different rate and time

    2) The shock is absorbed by converting the energy into heat energy.

Leaf-Type Spring Gear

1. Many aircraft utilize flexible spring steel, aluminum, or composite struts that receive the impact of landing and return it to the airframe to dissipate at a rate that is not harmful.
2. The gear flexes initially and forces are transferred as it returns to its original position.
3. *The most common* example of this type of non-shock absorbing landing gear are the thousands of single-engine Cessna aircraft that use it.
4. Landing gear struts of this type made from composite materials are lighter in weight with greater flexibility and do not corrode.

Rigid

1. Before the development of curved spring steel landing struts, many early aircraft were designed with rigid, welded steel landing gear struts.
2. Shock load transfer to the airframe is direct with this design.
3. Use of pneumatic tires aids in softening the impact loads.
4. *Modern aircraft that use* skid-type landing gear make use of rigid landing gear with no significant ill effects.
5. Rotorcraft, for example, typically experience low impact landings that are able to be directly absorbed by the airframe through the rigid gear (skids).

Bungee Cord

1. The use of bungee cords on non-shock absorbing landing gear is common.

2. The geometry of the gear allows the strut assembly to flex upon landing impact.

3. Bungee cords are positioned between the rigid airframe structure and the flexing gear assembly to take up the loads and return them to the airframe at a non-damaging rate.

4. The bungees are made of many individual small strands of elastic rubber that must be inspected for condition.

5. Solid, donut-type rubber cushions are also used on some aircraft landing gear

Hydraulic Landing Gear Retraction Systems

1. Devices used in a typical hydraulically operatedlanding gear retraction system include actuatingcylinders, selector valves, uplocks, downlocks, sequencevalves, tubing, and other conventional hydraulic components.
2. These units are so interconnected that they permit properly sequenced retraction and extension of the landing gear and thelanding gear doors.
3. First, consider what happenswhen the landing gear is retracted. As theselector valve (figure 9-14) is moved to the "up"position, pressurized fluid is directed into the gearup line.
4. The fluid flows to each of eight units; tosequence valves C and D, to the three gear down·locks, to the nose gear cylinder, and to the twomain actuating cylinders.
5. Notice what happens to the fluid flowing to sequencevalves C and D in figure 9-14. Since thesequence valves are closed, pressurized fluid cannotflow to the door cylinders at this time. Thus, thedoors cannot close. But the fluid entering the threedownlock cylinders is not delayed; therefore, thegear is unlocked.
6. At the same time, fluid also entersthe up side of each gear-actuating cylinder and thegears begin to retract.
7. The nose gear completesretraction and engages its uplock fint, because ofthe small size of its actuating cylinder. Also, sincethe nose gear door is operated solely by linkagefrom the nose gear, this door closes. Meanwhile, themain landing gear is still retracting, forcing fluidto leave the downside of each main gear cylinder.
8. This fluid flows unrestricted through an orificecheck valve, opens the sequence check valve A or B,and flows through the landing-gear selector valveinto the hydraulic system return line.
9. Then, as themain gear reaches the fully retracted position andengages the spring-loaded uplock, gear linkagestrikes the plungers of sequence valves C and D.
10. This opens the sequence check valves and allowspressurized fluid to flow into the door cylinders,closing the landing gear doors.

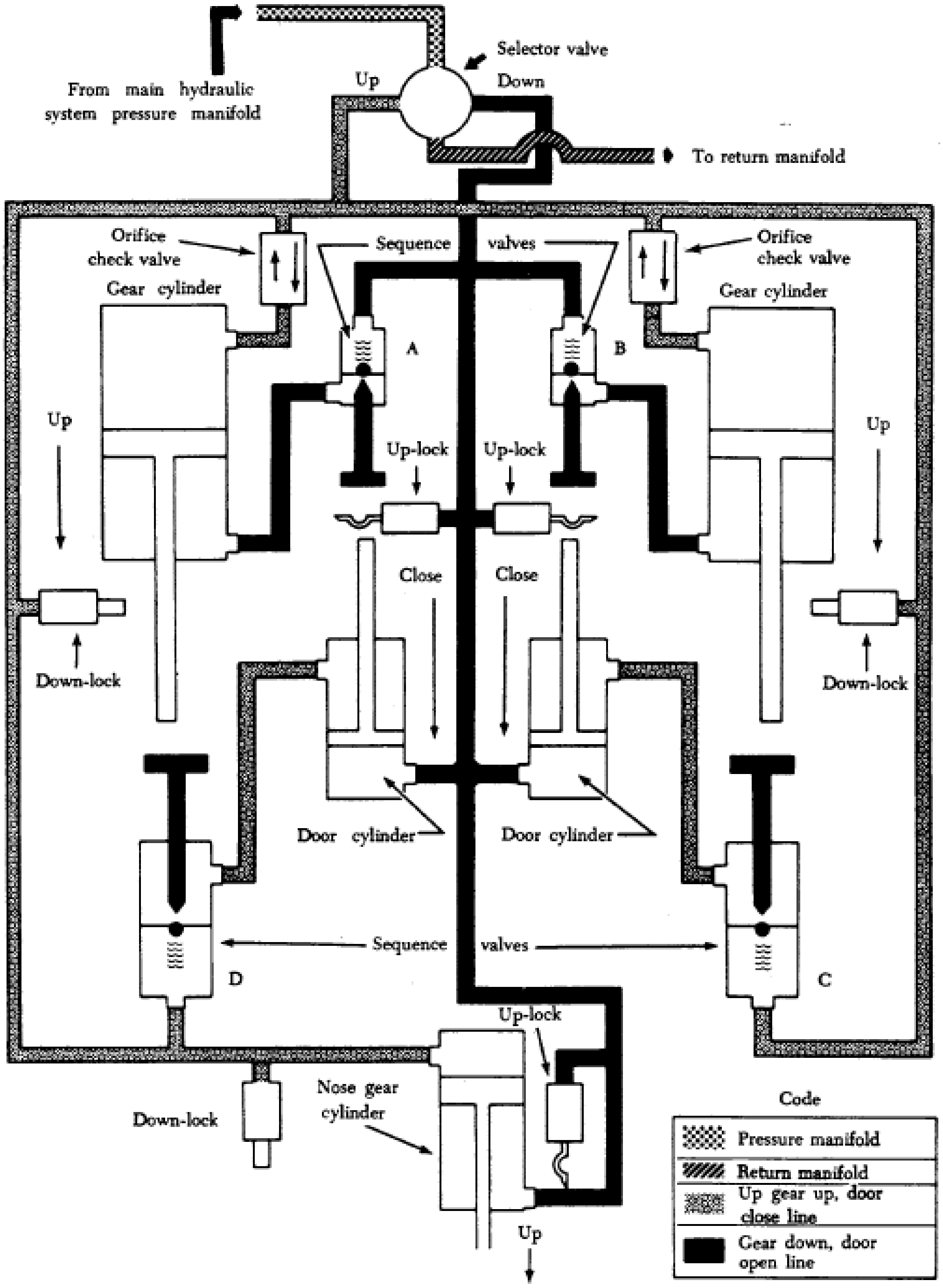


FIGURE 9–14. Hydraulic landing gear retraction system schematic.

UNITII

DIRECT MECHANICAL CONTROL (CONVENTIONAL CONTROL SYSTEM)

1. The linkage from cabin to control surface can be fully mechanical if the aircraft size and its flight envelop allow.
2. Two types of mechanical systems are used: push-pull rods and cable-pulley.

PUSH-PULL RODS SYSTEM

1. A sequence of rods links the control surface to the cabin input.
2 Bell-crank levers are used to change the direction of the rod routings
3. 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).
4. First of all the linkage must be stiff, to avoid any unwanted deflection during flight and due to fuselage elasticity.
5. Second, axial instability during compression must be excluded;

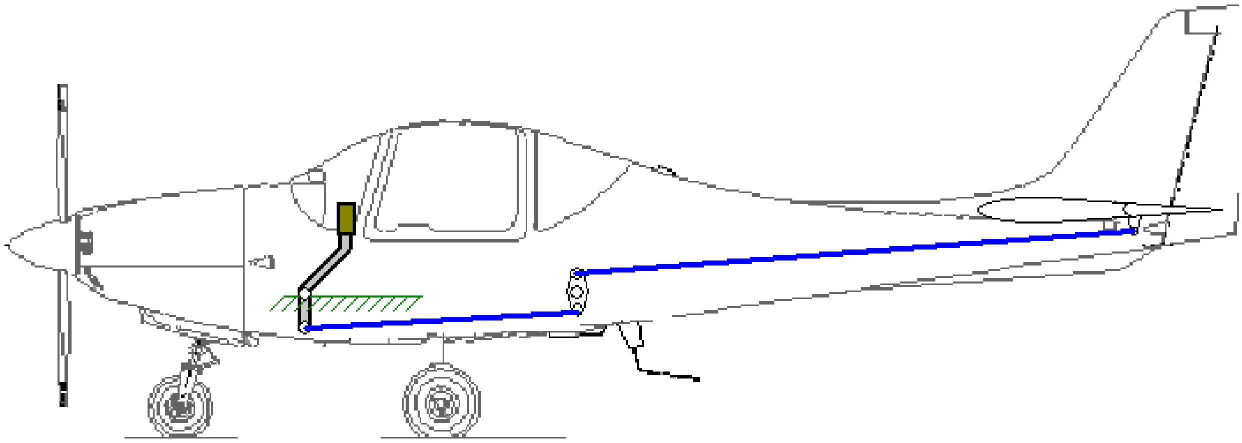


Fig 6.2sketches the push-pull control rod system between the elevator and the cabin control column

6. 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.

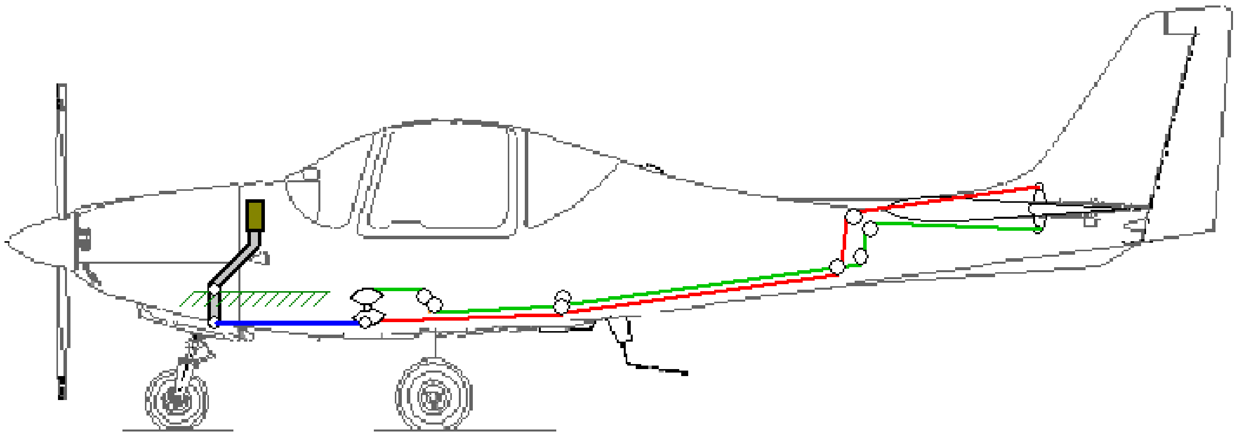


Fig 6.3

CABLE-PULLEY SYSTEM,

1. Where couples of cables are used in place of the rods.
2. In this case pulleys are used to alter the direction of the lines,
3. Idlers to reduce any slack due to structure elasticity, cable strands relaxation or thermal expansion.
4. Frequently the cable-pulley solution is preferred, because is more flexible and allows reaching more remote areas of the airplane.
5. An example is sketched in fig. 6.3, where the cabin column is linked via a rod to a quadrant, which the cables are connected to.

Fly-By-Wire

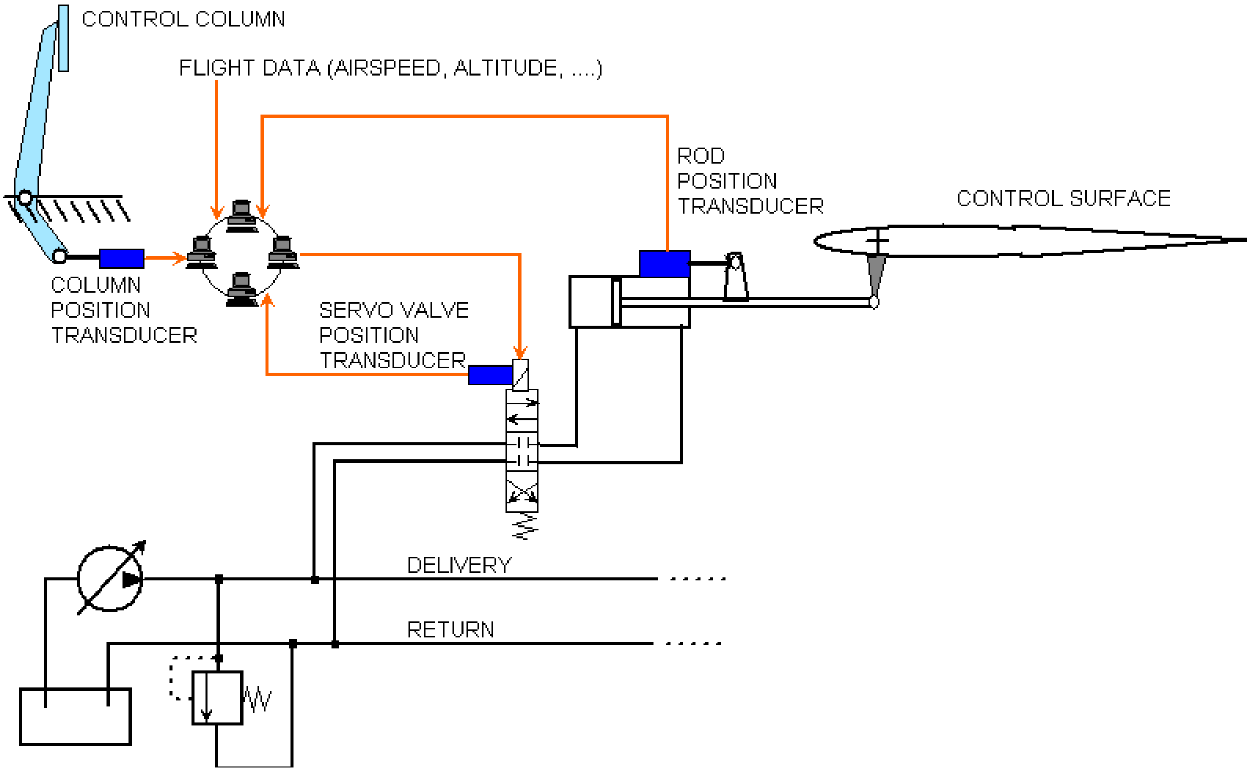
1. In the 70's the fly-by-wire architecture was developed, starting as an analogue technique and later ontransformed into digital.
2. It was first developed for military aviation, where it is now a common solution;
3. the supersonic Concorde can be considered a first civil aircraft equipped with a (analogue) fly-by-wire system,
4. In the 80's the digital technique was imported from military into civil aviation by Airbus, first with the A320, then followed by A319, A321, A330, A340, Boeing 777 and A380 .

WORKING PRINCIPLES:

1. The pilot's demand is first of all transduced into electrical signal in the cabin and sent to a group of independent computers
2. The computers sample also data concerning the flight conditions and servo-valves and actuators positions;
3. In general the following data are sampled and processed:
    1. pitch, roll, yaw rate and linear accelerations;
    2. angle of attack and sideslip;
    3. airspeed/mach number, pressure altitude and radio altimeter indications;
    4. stick and pedal demands; other cabin commands such as landing gear condition, thrust lever position, etc.
4. The pilot's demand is then processed and sent to the actuator
5. The full system has high redundancy to restore the level of reliability of a mechanical or hydraulic system.

MODES OF OPERATION OF FBW:

1. For civil fly-by-wire aircraft in normal operation the flight control changes according to the flight mode: ground, take-off, flight and flare.
2. Transition between modes is smooth and the pilot is not affected in its ability to control the aircraft:
3. **In Ground Mode** the pilot has control on the nose wheel steering as a function of speed, after lift-off the envelope protection is gradually introduced
4. **Flight Mode** the aircraft is fully protected by exceeding the maximum negative and positive load factors, angle of attack, stall, airspeed/Mach number, pitch attitude, roll rate, bank angle etc;
5. **Flare Mode**, where automatic trim is deactivated and modified flight laws are used for pitch control.
6. The probability of failure for military airplane is 2×10^{-6} per flight hour
7. The probability of failure for civil airplane is 2×10^{-6} per flight hour



8.

ADVANTAGES OF FLY-BY-WIRE

1. Flight envelope protection
2. Increase of stability and handling qualities across the full flight envelope
3. Turbulence suppression and consequent decrease of fatigue loads and increase of Passengercomfort;
4. Drag reduction by an optimised trim setting;
5. Higher stability during release of tanks and weapons;
6. Easier interfacing to auto-pilot and other automatic flight control systems;
7. Weight reduction
8. Maintenance reduction;
9. Reduction of airlines' pilot training costs

Power operated and power assisted

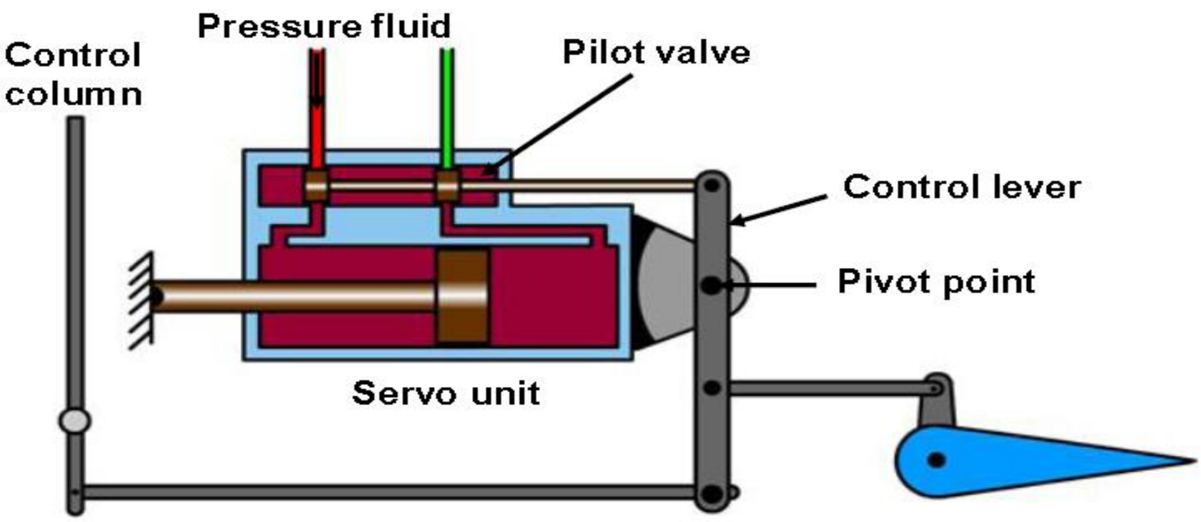
1. Aircraft with cruise speeds of approximately 300 knots and faster develop significant air loads on the control surfaces that are difficult for the pilot to overcome when operating the controls without mechanical advantage.
2. As a result, aircraft in this category will typically employ hydraulically operated flight controls.
3. Conventional cable or pushrod systems are installed in the aircraft as usual, but tied into a power transmission quadrant.
4. When the system is activated, the pilot's control inputs do not go directly to individual control surfaces.
5. Instead, the inputs open and close hydraulic valves that direct hydraulic fluid to individual actuators. The actuator moves the control surface to the requested position.
6. There are two primary methods of providing for hydraulic control system failure.

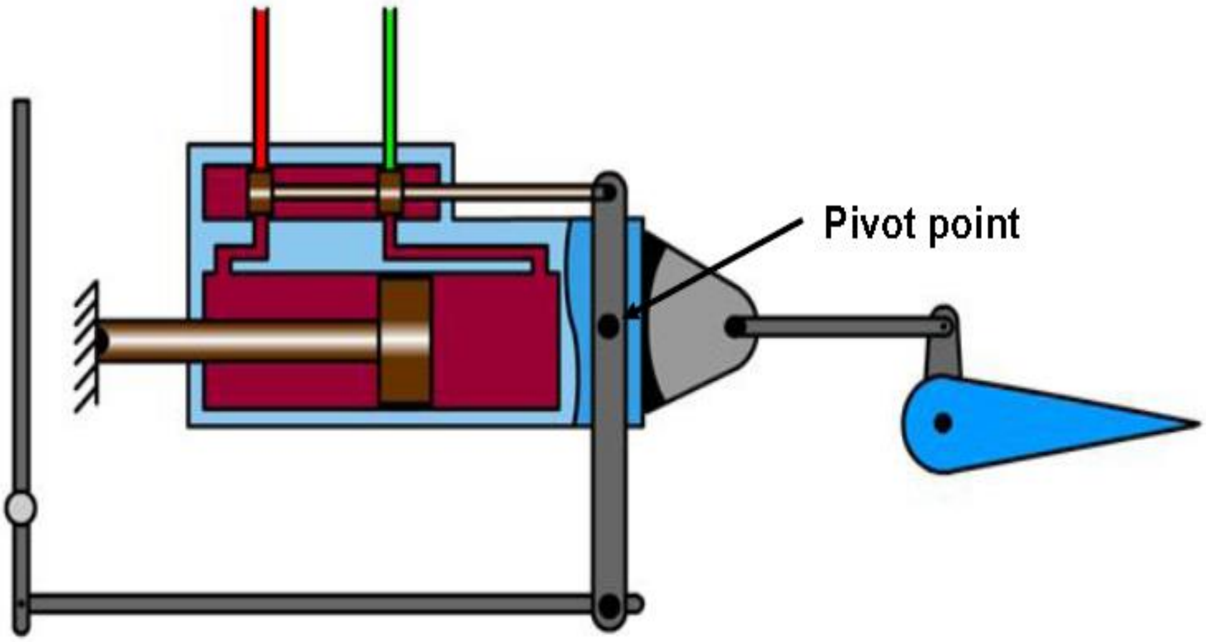
Power assisted control

1. The pilot's control is connected to the control surface through push pull rod and control lever.
2. E.g., control column to initiate a climb say, the control lever pivots about point 'X' and Moving the elevators up**.**
3. At the same time, the control valve pistons are displaced and this allows oil from the hydraulic system to flow to the left hand side of the actuating jack piston.
4. The rod of which is secured to the aircraft's structures.
5. The reaction of the pressure exerted on the piston causes the whole servo unit, and control lever, to move to the left because of the greater control effort produced.
6. The pilot is assisted in making further upward movement of the elevator.

Fully powered control

1. In this system pilot control is connected to the control lever only while servo-unit directly connected to the control surface.
2. Thus, the effort required by the pilot to move the control column is simply that needed to move the control lever and control valve piston.
3. It does not vary with the effort required to move the control surface, which is supplied solely by servo-unit hydraulic power.
4. Since no forces are transmitted back to the pilot. The pilot has no feel of the aerodynamic load acting on the control surfaces.
5. It is necessary to incorporate an 'artificial feel' device connected between the pilot's controls and servo-unit control lever.
6. A commonly used system for providing artificial feel is the one known as 'q' feel.
7. In this system, the feel force varies with dynamic pressure of the air, the pressure being sensed by pitot –tube or bellows type sensing element.
8. The sensing element connected in the hydraulic powered controls.
9. The hydraulic unit produces control forces dependent on the amount of control movement and forward speed of the aircraft.





Autopilot Systems

Definition

An aircraft automatic pilot system controls the aircraft without the pilot directly maneuvering the controls. The autopilot maintains the aircraft's attitude and/or direction and returns the aircraft to that condition when it is displaced from it. Automatic pilot systems are capable of keeping aircraft stabilized laterally, vertically, and longitudinally.

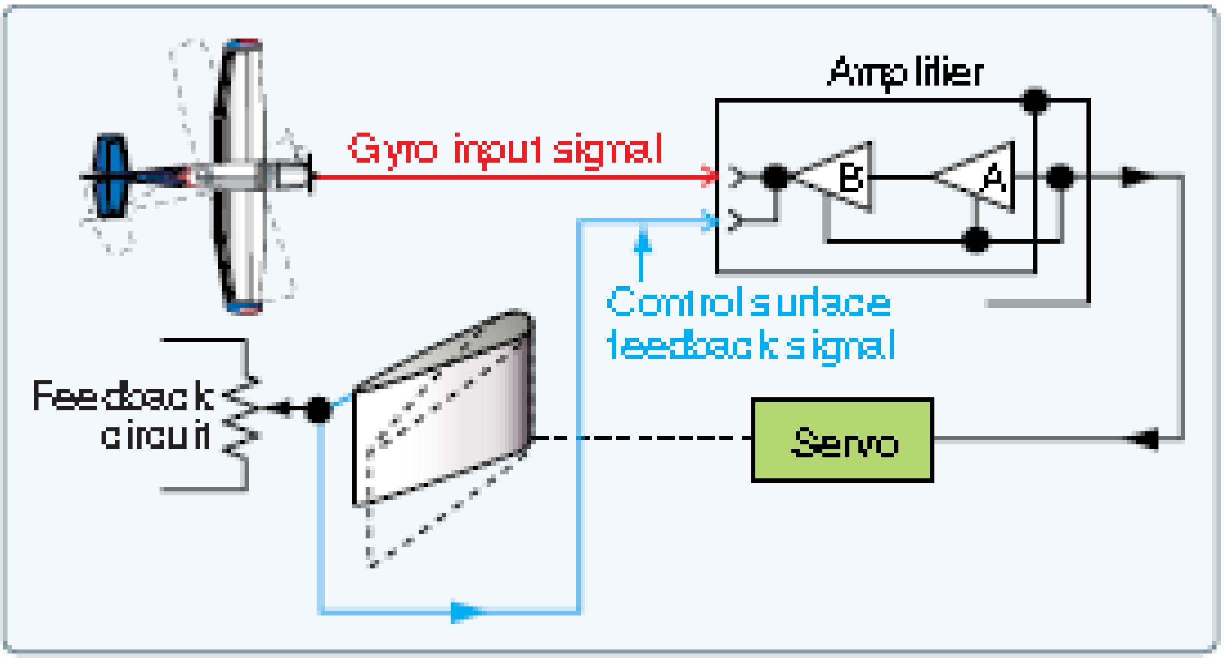
The primary purpose of an autopilot system:

1. To reduce the work strain and fatigue of controlling the aircraft during long flights. Most autopilots have both manual and automatic modes of operation.
2. In the manual mode, the pilot selects each maneuver and makes small inputs into an autopilot controller.
3. The autopilot system moves the control surfaces of the aircraft to perform the maneuver.
4. In automatic mode, the pilot selects the attitude and direction desired for a flight segment. The autopilot then moves the control surfaces to attain and maintain these parameters.

Functions of Autopilot systems:

1. Provide for one-, two-, or three-axis control of an aircraft.
2. Single axis autopilotcontrol the ailerons only and usually found on light aircraft.
3. Two-axis autopilots that control the ailerons and elevators.
4. Three-axis autopilots control the ailerons, elevators, and the rudder.
5. Two-and three axis autopilot systems can be found on aircraft of all sizes.

Basis for Autopilot Operation



.**WORKING PRINCIPLES:**

1. The automatic pilot system flies the aircraft by using electrical signals developed in gyro-sensing units.
2. These units are connected to flight instruments that indicate direction, rate of turn, bank, or pitch.
3. If the flight attitude or magnetic heading is changed, electrical signals are developed in the gyros.
4. These signals are sent to the autopilot computer/amplifier and are used to control the operation of servo units.
5. A servo for each of the three control channels converts electrical signals into mechanical force, which moves the control surface in response to corrective signals or pilot commands.

Rudder Channel

1. Receives two signals that determine when and how much the rudder moves.
2. The first signal is a course signal derived from a compass system. As long as the aircraft remains on the magnetic heading it was on when the autopilot was engaged, no signal develops.
3. Butany deviation causes the compass system to send a signal to the rudder channel that is proportional to the angular displacement of the aircraft from the preset heading.
4. The second signal received by the rudder channel is the rate signal that provides information anytime the aircraft is turning about the vertical axis.
5. This information is provided by the turn-and-bank indicator gyro.
6. When the aircraft attempts to turn off course, the rate gyro develops a signal proportional to the rate of turn, and the course gyro develops a signal proportional to the amount of displacement.
7. The two signals are sent to the rudder channel of the amplifier, where they are combined and their strength is increased. The amplified signal is then sent to the rudder servo.
8. The servo turns the rudder in the proper direction to return the aircraft to the selected magnetic heading.
9. When the two signals are equal in magnitude, the servo stops moving.
10. As the aircraft arrives on course, the course signal reaches a zero value, and the rudder is returned to the streamline position by the follow-up signal.

Aileron Channel

1. Receives its input signal from a transmitter located in the gyro horizon indicator.
2. Any movement of the aircraft about its longitudinal axis causes the gyro-sensing unit to develop a signal to correct for the movement.

3. This signal is amplified, phase detected, and sent to the aileron servo, which moves the aileron control surfaces to correct for the error.
4. When the two signals are equal in magnitude, the servo stops moving.
5. When the aircraft has returned to level flight roll attitude, the input signal is again zero. At the same time, the control surfaces are streamlined, and the follow-up signal is zero.

Elevator Channel

1. These circuits are similar to those of the aileron channel, with the exception that the elevator channel detects and corrects changes in pitch attitude of the aircraft.
2. For altitude control, a remotely mounted unit containing an altitude pressure diaphragm is used.
3. The signals control the pitch servos, which move to correct the error. An altitude select function causes the signals to continuously be sent to the pitch servos until a preselected altitude has been reached.
4. The aircraft then maintains the preselected altitude using altitude hold signals.

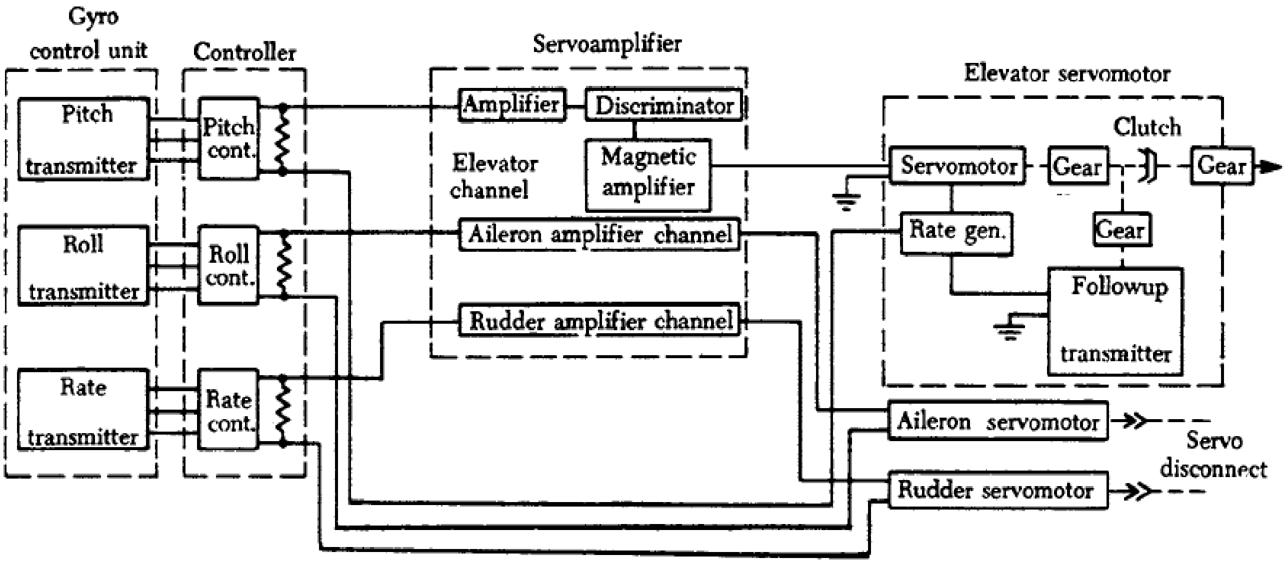


FIGURE 12–74. Autopilot block diagram.

Engine Control Systems

- ❖ To allow the engine to perform at maximum efficiency for a given condition
- ❖ Aids the pilot to control and monitor the operation of the aircraft's power plant
- ❖ Originally, engine control systems consisted of simple mechanical linkages controlled by the pilot then evolved and became the responsibility of the third pilot-certified crew member, the flight engineer
- ❖ By moving throttle levers directly connected to the engine, the pilot or the flight engineer could control fuel flow, power output, and many other engine parameters.
- ❖ Following mechanical means of engine control came the introduction of analog electronic engine control.
- ❖ Analog electronic control varies an electrical signal to communicate the desired engine settings
- ❖ It had its drawbacks including common electronic noise interference and reliability issues
- ❖ Full authority analogue control was used in the 1960s.
- ❖ It was introduced as a component of the Rolls Royce Olympus 593 engine of the supersonic transport aircraft Concorde. However the more critical inlet control was digital on the production aircraft. In the 1970s NASA and Pratt and Whitney experimented with the first experimental FADEC, first flown on an F-111 fitted with a highly modified Pratt & Whitney TF30 left engine

- Pratt & Whitney F100 – First Military Engine
- Pratt & Whitney PW2000 - First Civil Engine fitted with FADEC
- Pratt & Whitney PW4000 - First commercial "dual FADEC" engine.
- The Harrier II Pegasus engine by Dowty & Smiths Industries Controls - The first FADEC in service

Functions

- FADEC works by receiving multiple input variables of the current flight condition including air density, throttle lever position, engine temperatures, engine pressures, and many other parameters
- The inputs are received by the EEC and analyzed up to 70 times per second
- Engine operating parameters such as fuel flow, stator vane position, bleed valve position, and others are computed from this data and applied as appropriate.
- It controls engine starting and restarting.
- Its basic purpose is to provide optimum engine efficiency for a given flight condition.
- It also allows the manufacturer to program engine limitations and receive engine health and maintenance reports. For example, to avoid exceeding a certain engine temperature, the FADEC can be programmed to automatically take the necessary measures without pilot intervention.
- The flight crew first enters flight data such as wind conditions, runway length, or cruise altitude, into the flight management system (FMS). The FMS uses this data to calculate power settings for different phases of the flight.
- At takeoff, the flight crew advances the throttle to a predetermined setting, or opts for an auto-throttle takeoff if available.
- The FADECs now apply the calculated takeoff thrust setting by sending an electronic signal to the engines
- There is no direct linkage to open fuel flow. This procedure can be repeated for any other phase of flight
- In flight, small changes in operation are constantly made to maintain efficiency.
- Maximum thrust is available for emergency situations if the throttle is advanced to full, but limitations can't be exceeded
- The flight crew has no means of manually overriding the FADEC
- True full authority digital engine controls have no form of manual override available, placing full authority over the operating parameters of the engine in the hands of the computer
- If a total FADEC failure occurs, the engine fails
- If the engine is controlled digitally and electronically but allows for manual override, it is considered solely an EEC or ECU.
- An EEC, though a component of a FADEC, is not by itself FADEC. When standing alone, the EEC makes all of the decisions until the pilot wishes to intervene

Safety

- With the operation of the engines so heavily relying on automation, safety is a great concern.
- Redundancy is provided in the form of two or more, separate identical digital channels.
- Each channel may provide all engine functions without restriction.
- FADEC also monitors a variety of analog, digital and discrete data coming from the engine subsystems and related aircraft systems, providing for fault tolerant engine control

Applications

- FADECs are employed by almost all current generation jet engines, and increasingly in piston engines for fixed-wing aircraft and helicopters.
- The system replaces both magnetos in piston-engined aircraft, which makes costly magneto maintenance obsolete and eliminates carburetor heat, mixture controls and engine priming.

- Since, it controls each engine cylinder independently for optimum fuel injection and spark timing, the pilot no longer needs to monitor fuel mixture.
- More precise mixtures create less engine wear, which reduces operating costs and increases engine life for the average aircraft.
- Tests have also shown significant fuel savings

Advantages

- Better fuel efficiency
- Automatic engine protection against out-of-tolerance operations
- Safer as the multiple channel FADEC computer provides redundancy in case of failure
- Care-free engine handling, with guaranteed thrust settings
- Ability to use single engine type for wide thrust requirements by just reprogramming the FADECs
- Provides semi-automatic engine starting
- Better systems integration with engine and aircraft systems
- Can provide engine long-term health monitoring and diagnostics
- Reduces the number of parameters to be monitored by flight crews
- Due to the high number of parameters monitored, the FADEC makes possible "Fault Tolerant Systems" (where a system can operate within required reliability and safety limitation with certain fault configurations)
- Can support automatic aircraft and engine emergency responses (e.g. in case of aircraft stall, engines increase thrust automatically).

Disadvantages

- No form of manual override available, placing full authority over the operating parameters of the engine in the hands of the computer.
- If a total FADEC failure occurs, the engine fails.
- In the event of a total FADEC failure, pilots have no way of manually controlling the engines for a restart, or to otherwise control the engine.
- With any single point of failure, the risk can be mitigated with redundant FADECs
- High system complexity compared to hydromechanical, analogue or manual control systems
- High system development and validation effort due to the complexity.

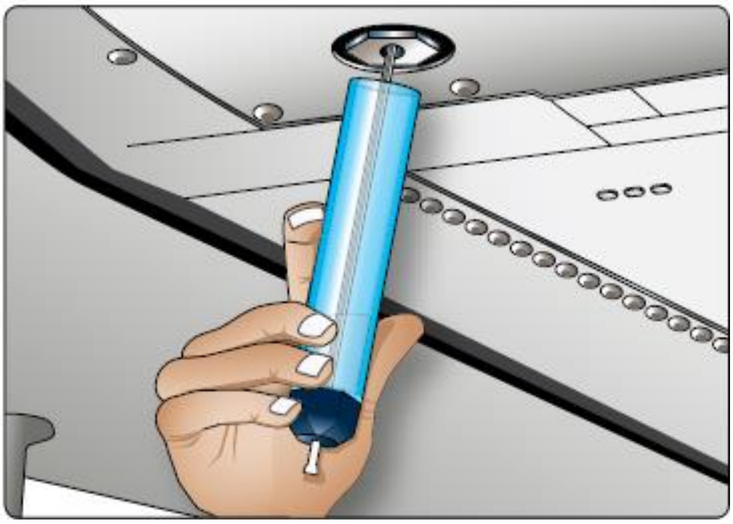
UNITIII

AIRCRAFT FUEL SYSTEMS

Fuel System Components

1. Fuel Tanks

1. There are three basic types of aircraft fuel tanks: rigid removable tanks, bladder tanks, and integral fuel tanks.
2. Most tanks are constructed of noncorrosive material(s). They are typically made to be vented either through a vent cap or a vent line.
3. Aircraft fuel tanks have a low area called a sump that is designed as a place for contaminants and water to settle.
4. The sump is equipped with a drain valve used to remove the impurities during preflight walk-around inspection.



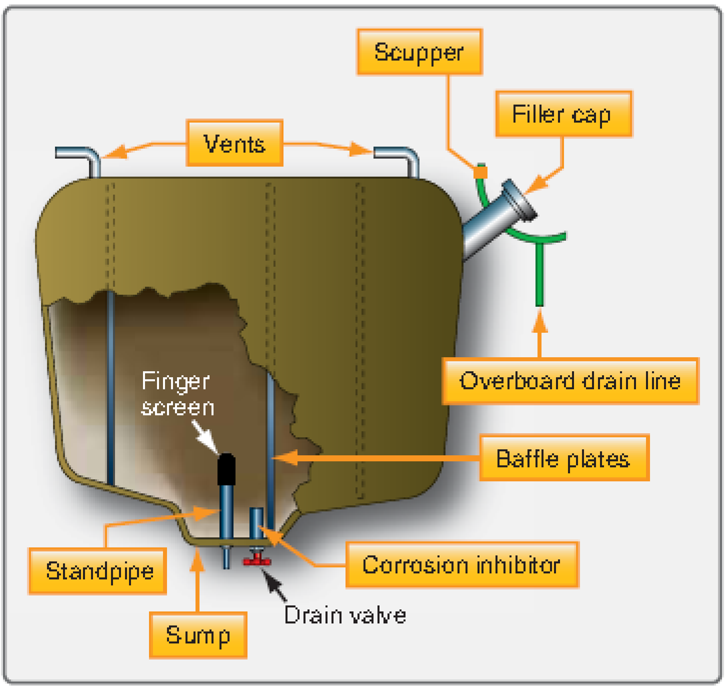
a. Rigid Removable Fuel Tanks

1. Normally found in many older model aircraft.

2. A rigid tank is made from 3003 or 5052 aluminum alloyor stainless steel and are riveted and seam welded to preventleaks.

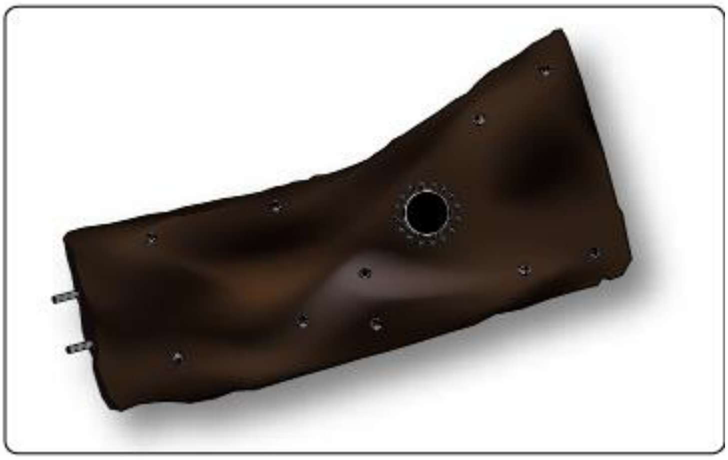
3. Many early tanks were made of a thin sheet steel coatedwith a lead/tin alloy called terneplate.

5. The terneplate tanks have folded and soldered seams.



Bladder Fuel Tanks

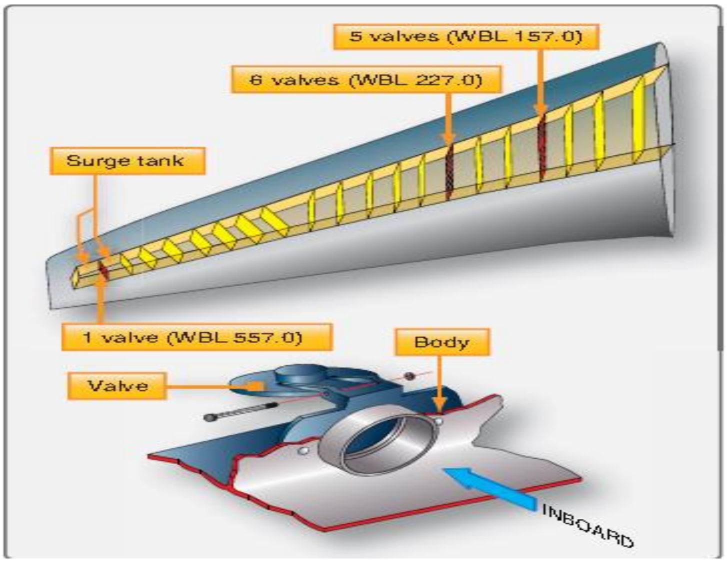
1. A fuel tank made out of a reinforced flexible material called a bladder tank can be used instead of a rigid tank.
2. A bladder tank does not require as large an opening in the aircraft skin to install.
3. The tank, or fuel cell as it is sometimes called, can be rolled up and put into a specially prepared structural bay or cavity through a small opening, such as an inspection opening.
4. Bladder tanks must be attached to the structure with clips or other fastening devices.
5. Bladder fuel tanks are used on aircraft of all size.
6. They are strong and have a long life.



Integral Fuel Tanks

1. Normally found on many aircraft, especially transport category and highperformance aircraft.

2. The sealed skin and structural members provide the highest volume of space available with the lowest weight.
3. This type of tank is called an integral fuel tank since it forms a tank as a unit within the airframe structure.
4. Integral fuel tanks in the otherwise unused space inside the wings are most common.
5. Aircraft with integral fuel tanks in the wings are said to have wet wings.
6. Baffle check valves are commonly used.
7. These valves allow fuel to move to the low, inboard sections of the tank but prevent it from moving outboard.



2. Fuel Lines and Fittings

1. Aircraft fuel lines can be rigid or flexible depending on location and application.
2. Rigid lines are often made of aluminum alloy and are connected with Army/Navy (AN) or military standard (MS) fittings.

3. Fuel Valves

1. There are many fuel valve uses in aircraft fuel systems.
2. They are used to shut off fuel flow or to route the fuel to a desired location.
3. Large aircraft fuel systems have numerous valves. Most simply open and close.
4. Fuel valves can be manually operated, solenoid operated, or operated by electric motor.

4. Hand-Operated Valves

1. There are three basic types of hand-operated valves used in aircraft fuel systems.
2. The cone-type valve and the poppettype valve are commonly used in light general aviation aircraft as fuel selector valves.
3. Gate valves are used on transport category aircraft as shutoff valves.

5. Fuel Pumps

1. All aircraft have at least one fuel pump to deliver clean fuel under pressure to the fuel metering device for each engine.
2. Engine-driven pumps are the primary delivery device.
3. Auxiliary pumps are used on many aircraft as well.
4. Auxiliary pumps are used to provide fuel under positive pressure to the engine-driven pump and during starting.
5. On many large aircraft, boost pumps are used to move fuel from one tank to another.
6. There are many different types of auxiliary fuel pumps in use.
7. Most are electrically operated, but some hand-operated pumps are found on older aircraft.

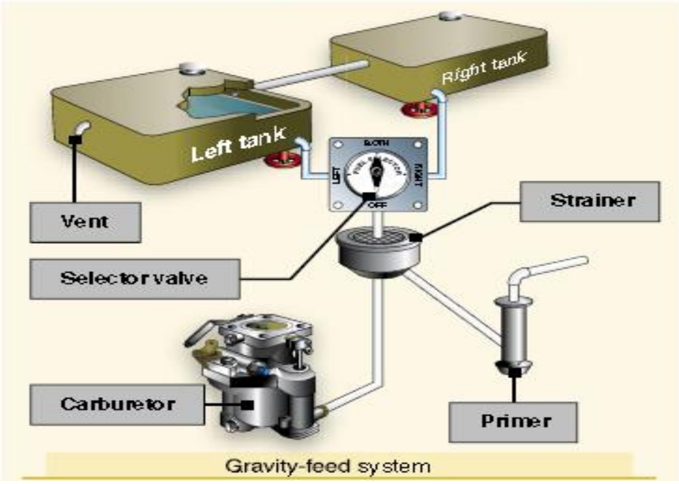
6. Fuel System Indicators

1. Aircraft fuel systems utilize various indicators.
2. All systems are required to have some sort of fuel quantity indicator.
3. Fuel flow, pressure, and temperature are monitored on many aircraft.
4. Valve position indicators and various warning lights and annunciations are also used.

Small Single-Engine Aircraft Fuel Systems

Gravity Feed Systems

1. High-wing aircraft with a fuel tank in each wing are common.
2. With the tanks above the engine, gravity is used to deliver the fuel.
3. The space above the liquid fuel is vented to maintain atmospheric pressure on the fuel as the tank empties.
4. The two tanks are also vented to each other to ensure equal pressure when both tanks feed the engine.
5. A single screened outlet on each tank feeds lines that connect to either a fuel shutoff valve or multiposition selector valve.
6. The shutoff valve has two positions: fuel ON and fuel OFF.
7. If installed the selector valve provides four options: fuel shutoff to the engine; fuel feed from the right wing tank only; fuel feed from the left fuel tank only; fuel feed to the engine from both tanks simultaneously.

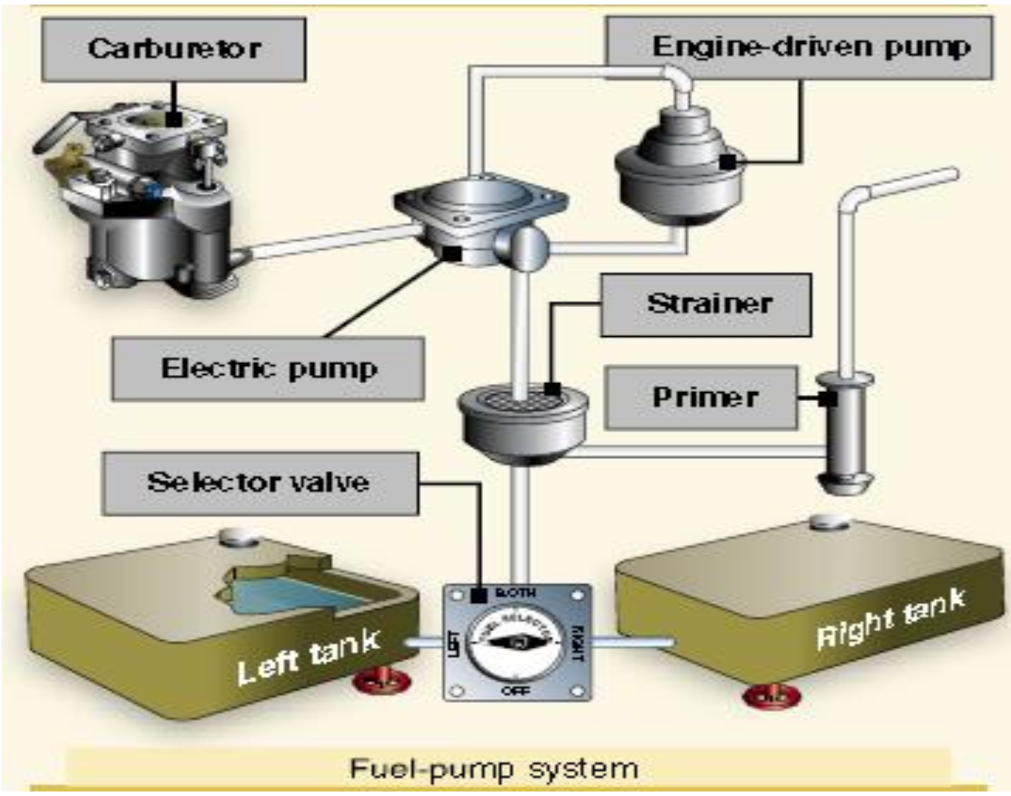


Gravity-feed system

8. Downstream of the shutoff valve or selector valve, the fuel passes through a main system strainer.
9. This often has a drain function to remove sediment and water.
10. From there, it flows to the carburetor or to the primer pump for engine starting.
11. Having no fuel pump, the gravity feed system is the simplest aircraft fuel system.

Pump Feed Systems

1. Low- and mid-wing single reciprocating engine aircraft cannot utilize gravity-feed fuel systems because the fuel tanks are not located above the engine.
2. Instead, one or more pumps are used to move the fuel from the tanks to the engine.
3. Each tank has a line from the screened outlet to a selector valve.
4. However, fuel cannot be drawn from both tanks simultaneously; if the fuel is depleted in one tank, the pump would draw air from that tank instead of fuel from the full tank.
5. Since fuel is not drawn from both tanks at the same time, there is no need to connect the tank vent spaces together.



6. From the selector valve (LEFT, RIGHT, or OFF), fuel flows through the main strainer where it can supply the engine primer.
7. Then, it flows downstream to the fuel pumps.
8. Typically, one electric and one engine-driven fuel pump are arranged in parallel.
9. They draw the fuel from the tank(s) and deliver it to the carburetor.
10. The two pumps provide redundancy.
11. The engine-driven fuel pump acts as the primary pump.
12. The electric pump can supply fuel should the other fail.
13. The electric pump also supplies fuel pressure while starting and is used to prevent vapor lock during flight at high altitude.

RECIPROCATING ENGINE LUBRICATION SYSTEMS

(A)DRY-SUMP SYSTEMS

1. Many reciprocating aircraft engines have pressure dry-sump lubrication systems.
2. The oil supply in this type of system is carried in a tank.
3. A pressure pump circulates the oil through the engine;
4. Scavenger pumps then return it to the tank as quickly as it accumulates in the engine sumps.
5. On multi-engine aircraft, each engine is supplied with oil from its own complete and independent system.
6. The principal units in a typical reciprocating engine dry-sump oil system include an oil supply tank, an engine oil pump, an oil cooler, an oil control valve, an actuator for an oil-cooler air-exit

control, a firewall shutoff valve, the necessary tubing, and quantity, pressure, and temperature indicators.

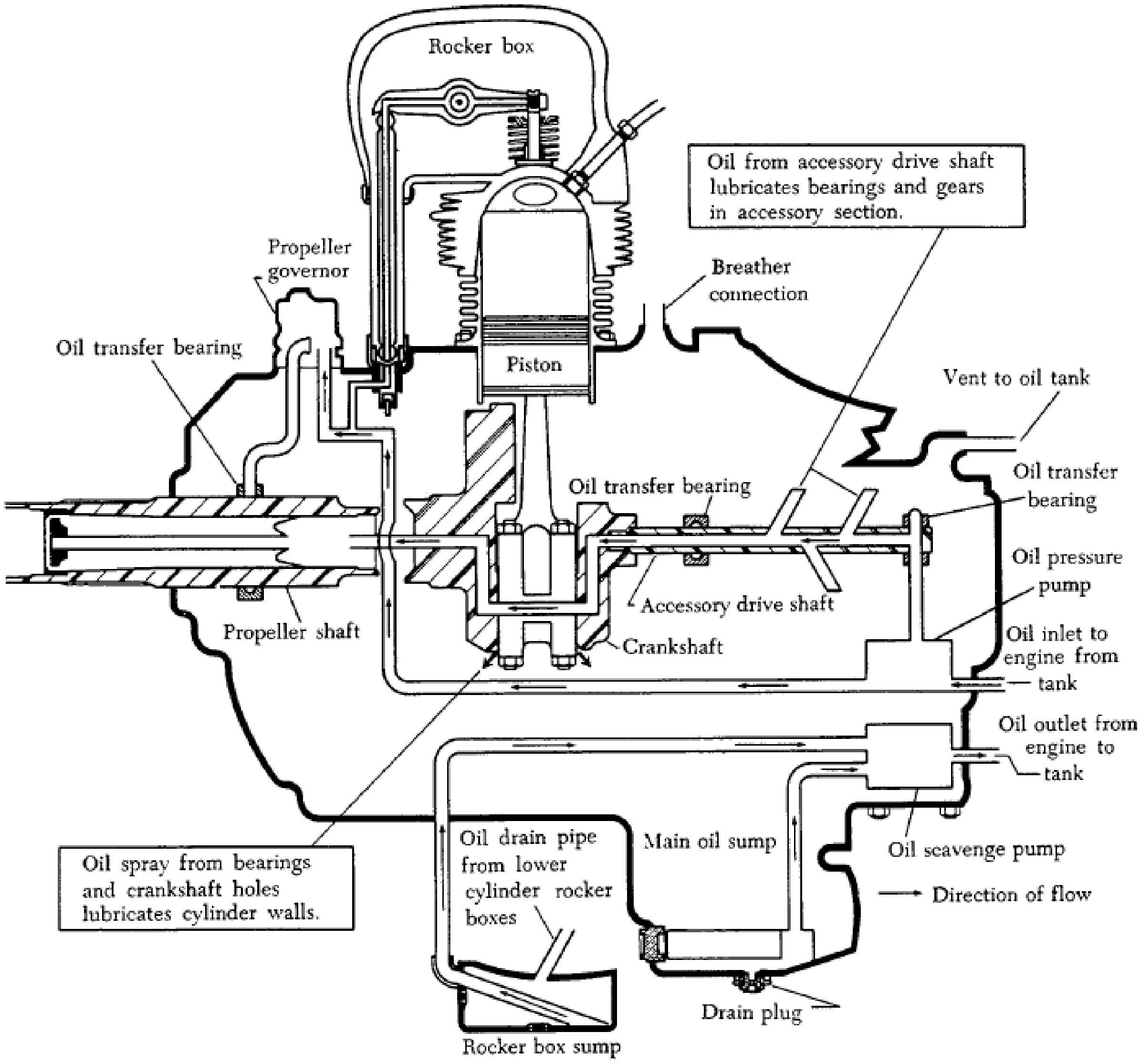


FIGURE 6–9. Schematic showing pressure dry-sump lubrication system.

7. The lubricating oil is distributed to the various moving parts of a typical internal-combustion engine by one of the three following methods: (1) Pressure, (2) splash, or (3)a combination of pressure and splash.

Pressure Lubrication

1. In a typical pressure-lubrication system, a mechanical pump supplies oil under pressure to the bearings throughout the engine.
2. The oil flows into the inlet or suction side of the oil pump through a line connected to the tank at a point higher than the bottom of the oil sump.
3. This prevents sediment which falls into the sump from being drawn into the pump.
4. The pump forces the oil into a manifold that distributes the oil through drilled passages to the crankshaft bearings and other bearings throughout the engine.

5. Oil flows from the main bearings through holes drilled in the crankshaft to the lower connecting rod bearings.
6. Each of these holes through which the oil is fed is located so that the bearing pressure at the point will be as low as possible.
7. Oil reaches a hollow camshaft (in an in-line or opposed engine), or a camplate or camdrum (in a radial engine], through a connection with the end bearing, or the main oil manifold; it then flows out to the various camshaft, camdrum, or camplate bearings and the cams.
8. The engine cylinder surfaces receive oil sprayed from the crankshaft and also from the crankpin bearings.
9. Since oil seeps-slowly through the small crankpin clearances before it is sprayed on the cylinder walls, considerable time is required for enough oil to reach the cylinder walls, especially on a cold day when the oil flow is more sluggish. This is one of the chief reasons for diluting the engine oil with gasoline for cold weather starting.

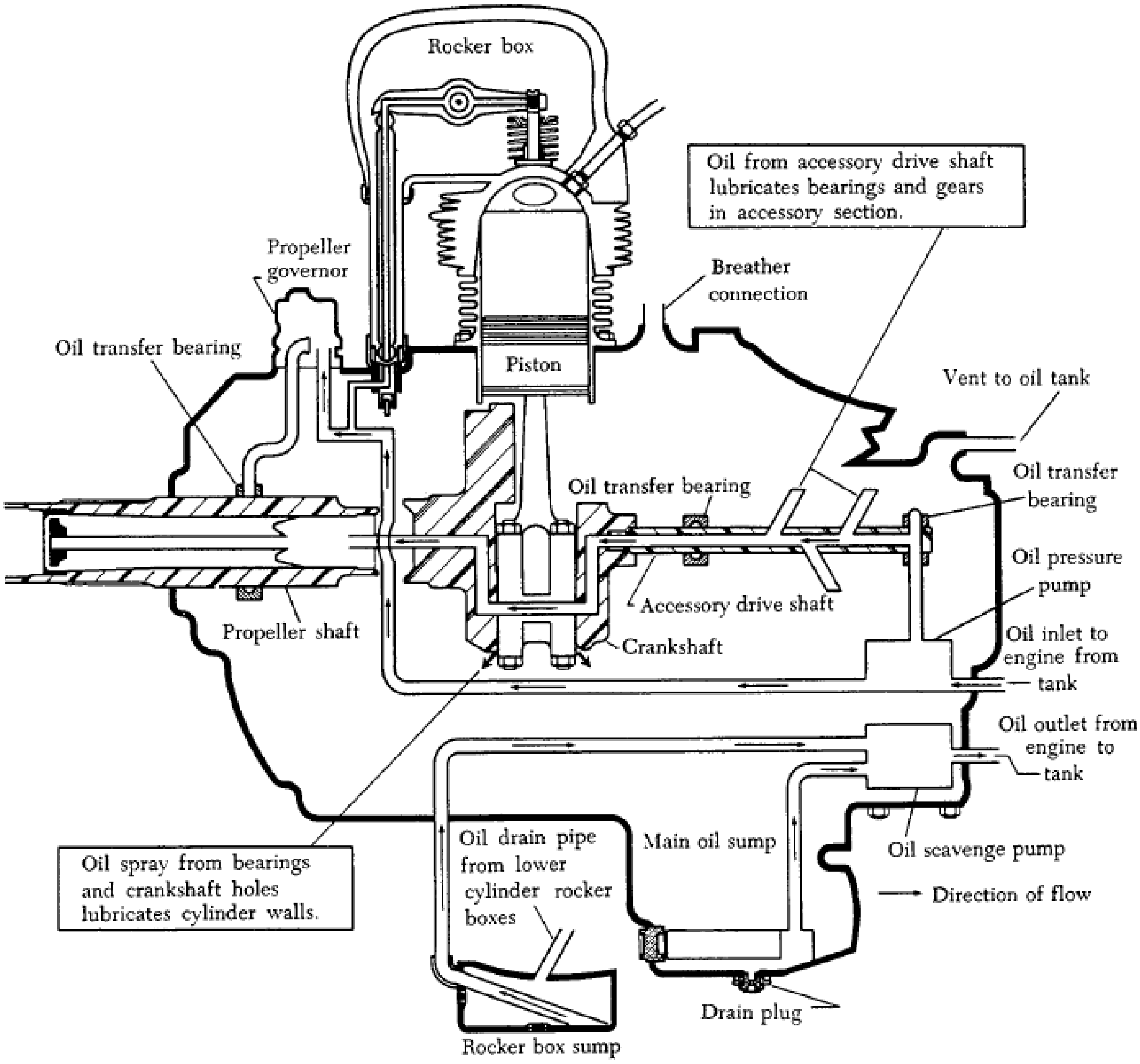


FIGURE 6–9. Schematic showing pressure dry-sump lubrication system.

Combination Splash-and-Pressure Lubrication

The pressure-lubrication system is the principal method of lubricating aircraft engines. Splash lubrication may be used in addition to pressure lubrication on aircraft engines,' but it is never used by itself; hence, aircraft-engine lubrication systems are always either the pressure type or the combination pressure-and-splash type, usually the latter.

The advantages of pressure lubrication are:

(1) Positive introduction of oil to the bearings.

12) Cooling effect caused by the large quantities of oil which can be (pumped) circulated through a bearing.

(3) Satisfactory lubrication in various attitudes of flight.

(B)WET-SUMP LUBRICATION

1. The system consists of a sump or pan in which the oil supply is contained.
2. The level (quantity) of oil is indicated or measured by a vertical rod that protrudes into the oil from an elevated hole on top of the crankcase.
3. In the bottom of the sump (oil pan) is a screen strainer having a suitable mesh or series of openings to strain undesirable particles from the oil and yet pass sufficient quantity to the inlet or (suction) side of the oil pressure pump.
4. The rotation of the pump, which is driven by the engine, causes the oil to pass around the outside of the gears in the manner illustrated in figure.
5. This develops a pressure in the crankshaft oiling system (drilled passage-holes).
6. The variation in the speed of the pump from idling to full-throttle operating range of the engine and the fluctuation of oil viscosity because of temperature changes are compensated by the tension on the relief valve spring.
7. The pump is designed to create a greater pressure than probably will ever be required to compensate for wear of the bearings or thinning out of oil.
8. The parts oiled by pressure throw a lubricating spray into the cylinder and piston assemblies.
9. After lubricating the various units on which it sprays, the oil drains back into the sump and the cycle is repeated.

The main disadvantages of the wet-sump system are:

(1)The oil supply is limited by the sump (oil pan) capacity.

(2) Provisions for cooling the oil are difficult to arrange because the system is a self-contained unit.

(3) Oil temperatures are likely to be higher on large engines because the oil supply is so close to the engine and is continuously subjected to the operating temperatures.

(4) The system is not readily adaptable to invert- ed flying since the entire oil supply will flood the engine.

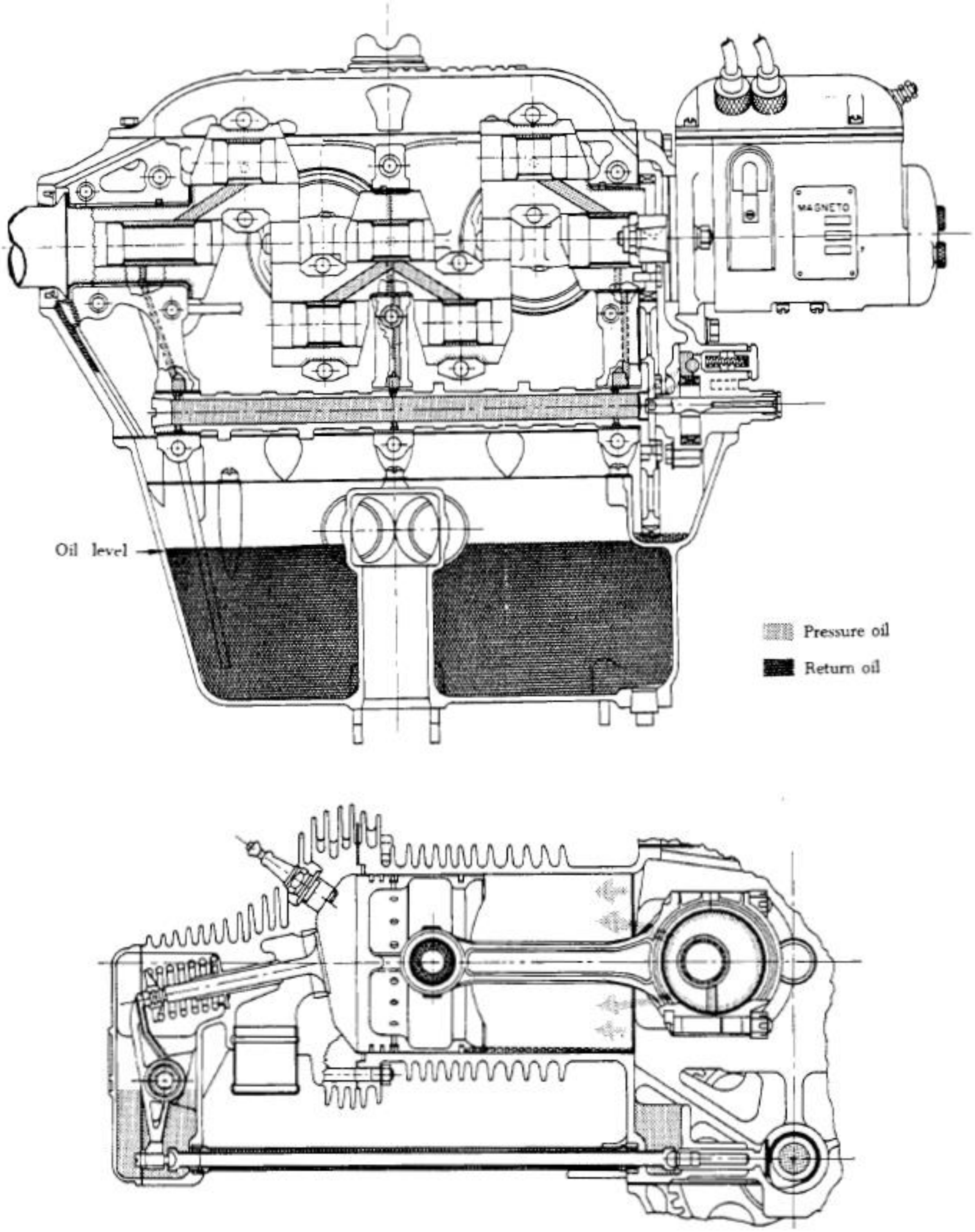


FIGURE 6–10. Schematic view of a typical wet-sump lubrication system.

TURBOJET DRY-SUMP LUBRICATION

1. In a turbojet dry-sump lubrication system, the oil supply is carried in a tank mounted on the engine.
2. With this type -of system, a larger oil supply can be carried and the temperature of the oil can readily be controlled.
3. The oil cooler may be air cooled or fuel cooled.

Oil Pump

1. The oil pump is designed to supply oil under pressure to the parts of the engine that require lubrication.
2. The three most common oil pumps are the gear, gear rotor, and piston, the gear type being the most commonly used. Each of these pumps has several possible configurations.

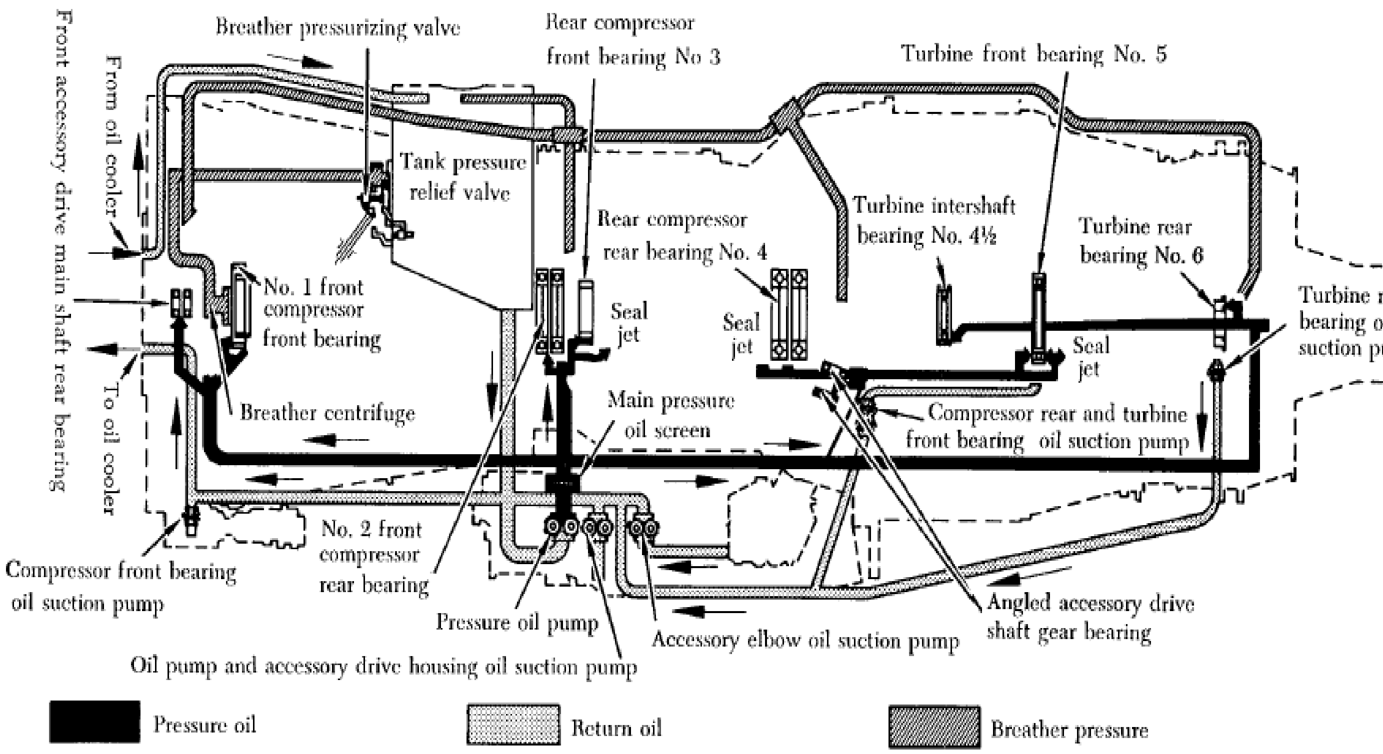


FIGURE 6–22. A turbojet dry-sump lubrication system.

Filter

1. Filters are removing foreign particles that may be in the oil.
2. One common type of oil filter uses a replaceable laminated paper element, such as those used in hydraulic systems.
3. In another type the filter element is made up of a series of spacers and screens

Oil Pressure Relief Valve

1. An oil pressure relief valve is to limit the maximum pressure within the system.
2. This valve is especially important if an oil cooler is incorporated in the system, since the coolers are easily ruptured because of their thin-wall construction.
3. The relief valve is preset to relieve pressure and bypass the oil back to the inlet side of the oil pump whenever the pressure exceeds the preset limit.

Oil Jets

1. Oil jets (or nozzles) are located in the pressure lines adjacent to, or within, the bearing compartments and rotor shaft couplings.
2. The oil from these nozzles is delivered in the form of an atomized spray.

3. Some engines use an air-oil mist spray, which is produced by tapping high-pressure bleed- air from the compressor to the oil nozzle outlet. This method is considered adequate for ball and roller bearings.
4. The oil jets are easily clogged because of the small orifice in their tips; consequently, the oil must be free of any foreign particles.
5. To prevent damage from clogged oil jets, main oil filters are checked frequently for contamination.

Lubrication System Gage Connections

1. The oil pressure gage measures the pressure of the lubricant as it leaves the pump on its way to the oil jets.
2. Two of the most common methods of obtaining oil temperature indications are: (1) **A** thermo-couple fitting in the oil line or (2) an oil temperature bulb inserted in the oil line.
3. The oil pressure gage connection is located in the pressure line between the pump and the various points of lubrication.
4. The oil temperature gage connection usually is located in the pressure inlet to the engine.

Lubrication System Vents

1. Vents or breathers are lines or openings in the oil tanks or accessory cases of the various engines, depending on whether the engine has a dry-or wet-sump lubrication system.
2. The vent in an oil tank keeps the pressure within the tank from rising above or falling below that of the outside atmosphere.

Lubrication System Check Valve

1. Check valves to prevent reservoir oil from seeping (by gravity) through the oil pump elements and high-pressure lines into the engine after shutdown.
2. Check valves, by stopping flow in an opposite direction, prevent accumulations of undue amounts of oil in the accessory gearbox, compressor rear housing, and combustion chamber.

Lubrication System Thermostatic Bypass Valves

1. Thermostatic bypass valves are included in oil systems using an oil cooler.
2. The purpose is always to maintain proper oil temperature by varying the proportion of the total oil flow passing through the oil cooler.

Oil Coolers

1. Oil coolers are used to reduce the temperature of the oil to a degree suitable for recirculation through the system.
2. Two basic types of oil coolers in general use are the air-cooled oil cooler and the fuel-cooled oil cooler.
3. The fuel-cooled oil cooler acts as a fuel/oil heat exchanger in that the fuel cools the oil and the oil heats the fuel.
4. The air-cooled oil cooler normally is installed at the forward end of the engine.

TURBINE ENGINE WET-SUMP LUBRICATION SYSTEM

1. In some engines the lubrication system is of the wet-sump type, because only a few models of centrifugal-flow engines are in operation.

2. The components of a wet-sump system are similar to many of those of a dry-sump system.
3. The major difference between the two systems is the location of the oil reservoir.
4. The reservoir for the wet-sump oil system may be either the accessory gear case, which consists of the accessory gear casing and the front compressor bearing support casing (figure 6-33), or it may be a sump mounted on the bottom of the accessory case.

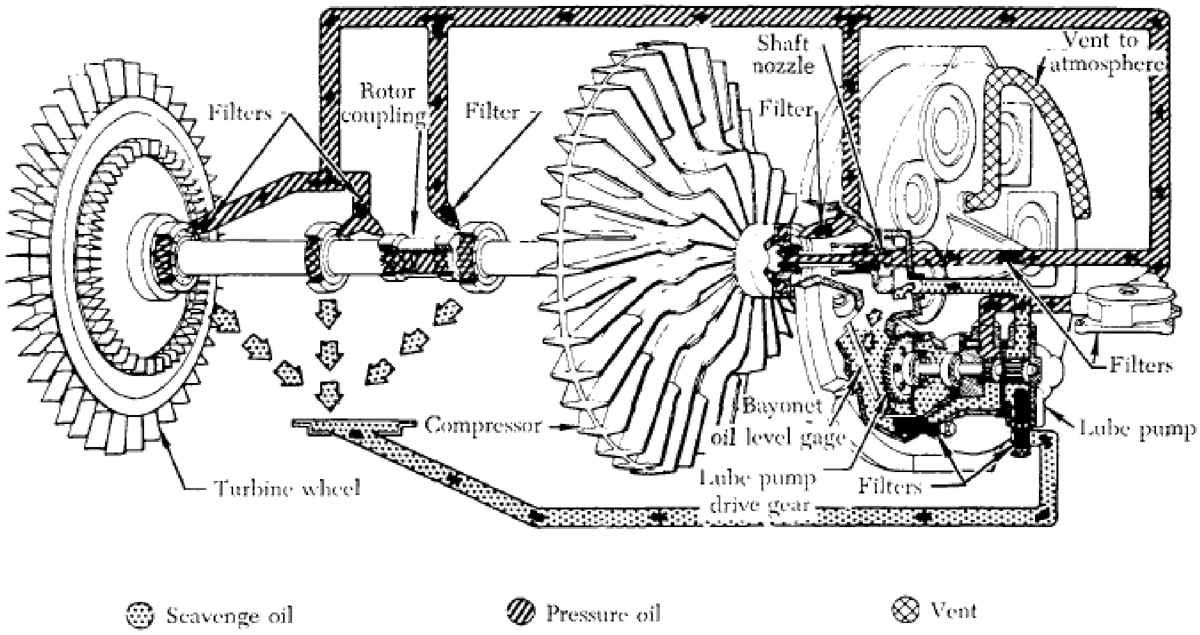


FIGURE 6–33. Turbojet engine wet-sump lubrication system.

Included in the wet-sump reservoir shown in figure 6-33 are the following components:

(1) **A bayonet-type gage** indicates the oil level in the sump.
(2) **Two or more finger strainers** (filters) are inserted in the accessory case for straining pressure and scavenged oil just before it leaves or enters the sump. These strainers aid the main oil strainer.
(3) **A vent or breather** equalizes pressure within the accessory casing.
(4) **A magnetic drain plug** may be provided to drain the oil and also to trap any ferrous metal particles in the oil. This plug should always be examined closely during inspections.
(5) **The presence of metal particles** may indicate gear or bearing failure. Provision may also be made for a temperature bulb and an oil pressure fitting.
(6) **The bearing and drive gears** in the accessory drive casing are lubricated by a splash system.

7 The oil for the remaining points of lubrication leaves the pump under pressure and passes through a filter to jet nozzles that direct the oil into the rotor bearings and couplings.

8 Most wet-sump pressure systems are variable-pressure systems in which the pump outlet pressure depends on the engine r.p.m.

9 **The scavenged oil** is returned to the reservoir (sump) by gravity and by pump suction. Oil from the front compressor bearing and the accessories drive coupling shaft drains directly into the reservoir.

10 Oil from the turbine coupling and the remaining rotor shaft bearings drains into a sump from which the oil is pumped by the scavenge element through a finger screen into the reservoir.

AIR-CYCLE COOLING SYSTEMS

1. **The system is composed** of a primary heat exchanger, primary heat exchanger bypass valve, flow limiters, refrigeration unit, main shutoff valve, secondary heat exchanger, refrigeration unit bypass valve, ram-air shutoff valve, and an air temperature control system. A cabin pressure regulator and a dump valve are included in the pressurization system.
2. Air bled from the compressors of both engines. The engine bleed lines are cross-connected and equipped with check valves to ensure a supply of air from either engine.
3. **A flow-limiting nozzle** to prevent the complete loss of pressure in the remaining system if a line ruptures, and to prevent excessive hot air bleed through the rupture.
4. **After air routed to the primary heat exchanger** and its bypass valve simultaneously Cooling air for the heat exchanger is obtained from an inlet duct and is exhausted overboard.
5. The air supply from the primary heat exchanger is controlled to a constant temperature of 300° F. by the heat exchanger bypass valve.
6. **The bypass valve** is automatically controlled by upstream air pressure and a downstream temperature-sensing element.
7. The cabin air is next routed through another flow limiter and a shutoff valve.
8. **The shutoff valve** is the main shutoff valve for the system and is controlled from the cockpit.
9. **From the shutoff valve**, the air is routed to the refrigeration unit bypass valve, to the compressor section of the refrigeration unit, and to the secondary heat exchanger.
10. **The bypass valve** automatically maintains compartment air at any preselected temperature between 60° F. and 125° F.
11. **Cooling air for the secondary heat exchanger** core is obtained from an inlet duct. Some installations use a turbine-driven fan to draw air through the heat exchanger; others use a hydraulically driven blower. After cooling the cabin air, the cooling air is exhausted overboard.
12. As the cabin air leaves the secondary heat exchanger, it is routed to the **expansion turbine,** which is rotated by the air pressure exerted on it. In performing this function, the air is further cooled before entering the **water separator**, where the moisture content of the air is reduced.
13. From the water separator the air is routed through the temperature sensor to the cabin.

14. **Air enters the cabin spaces** through a network of ducts and diffusers and is distributed evenly throughout the spaces. Some systems incorporate directional vents that can be rotated by the cabin occupants to provide additional comfort.
15. **An alternate ram-air system** is provided to supply the cabin with ventilating air if the normal system is inoperative or to rid the cabin areas of smoke, foul odors, or fumes which might threaten comfort, visibility, or safety.
16. The air conditioning and the ram air systems are controlled from a single switch in the cockpit. **This switch is a three-position switch for selecting off, normal, and ram.**
17. **In the "off'' position** (under nor· mal conditions) all cabin air conditioning, pressurization, and ventilating equipment is off.
18. **In the "normal" position** (under normal conditions) the air conditioning and pressurization equipment is functioning normally and ram air is off.
19. **In the "ram" position** (under normal conditions) the main shutoff valve closes, and the cabin air pressure regulator and the cabin safety dump valve are opened.
20. This allows ram air from the secondary heat exchanger cooling air inlet duct to be routed into the cabin air supply duct for cabin cooling and ventilation.
21. **Air pressure regulator and the safety dump valve energized open**, existing cabin air and incoming ram air are constantly being dumped overboard, ensuring a steady flow of fresh air through the cabin.

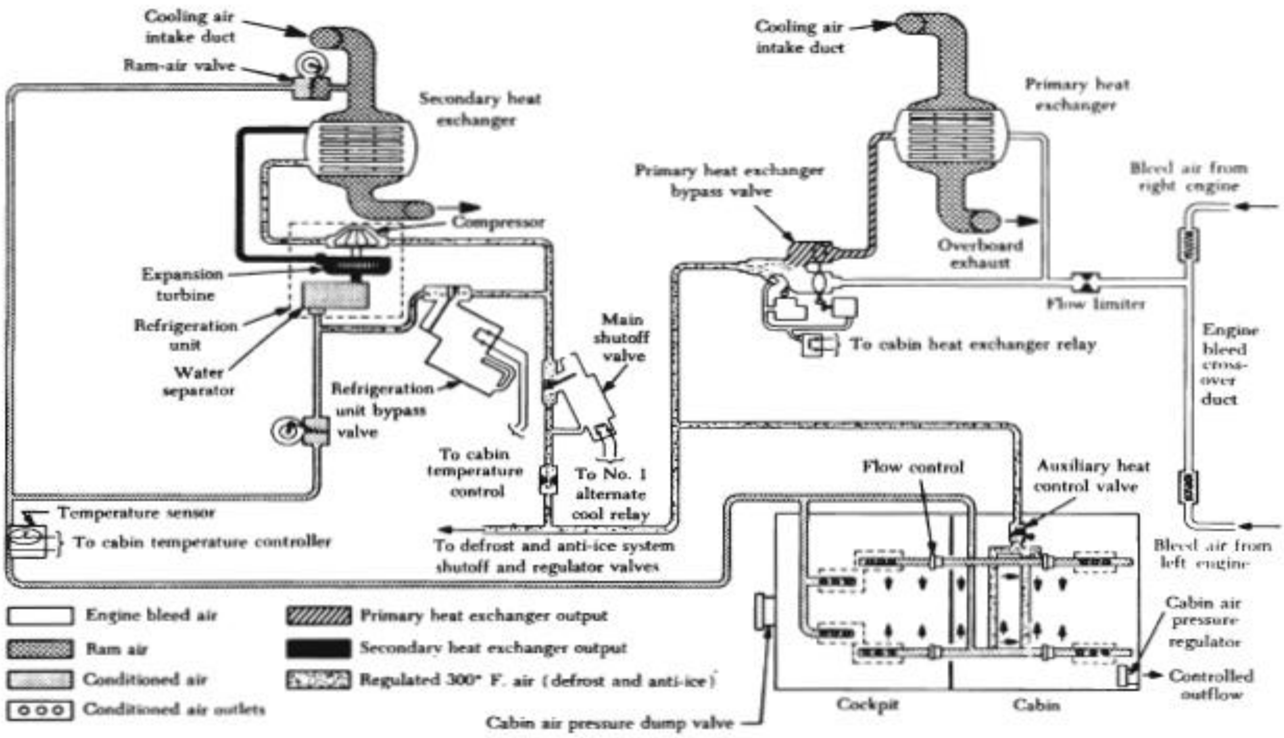
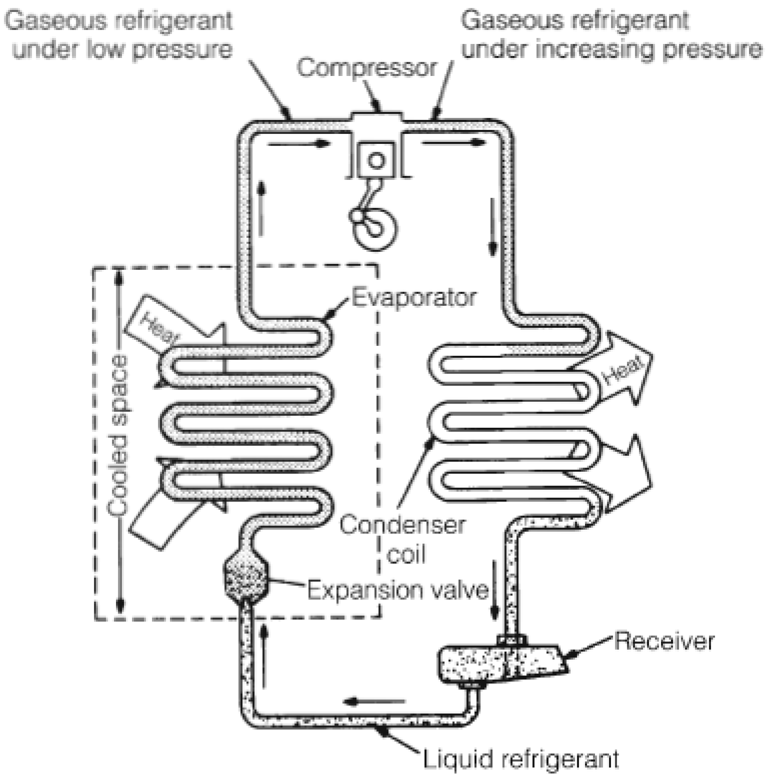


Fig. 8-15. *Cabin air conditioning and pressurization system flow schematic.*

VAPOR-CYCLE (FREON) COOLING SYSTEMS



Major components of a typical Freon system include:

- Evaporator
- Compressor
- Condenser
- Expansion valve

Compressor

- Powered by either an electric motor or by an air-turbine drive mechanism.
- The compressor increases the pressure of the Freon in vapor form.
- The result is that the Freon's high pressure raises the condensation temperature and results in the force necessary to circulate the Freon through the system.

Condenser

- Receives the Freon in a gaseous state
- where it passes through the heat exchanger that uses ambient air to remove heat.
- When heat is removed from the highpressure gas, Freon is converted to a liquid.

Receiver

- Takes this liquid Freon and serves as a reservoir;
- During heavy cooling demand, the reservoir might be near empty and
- During periods of reduced cooling demand the reservoir might be full.

- The main purpose for the receiver is to ensure that the thermostatic expansion valve is not starved for refrigerant under heavy cooling load conditions.

Sub cooler

- To reduce the liquid temperature after it leaves the receiver. Cooling the refrigerant at that point reduces the possibility of *premature vaporization (flash-off*

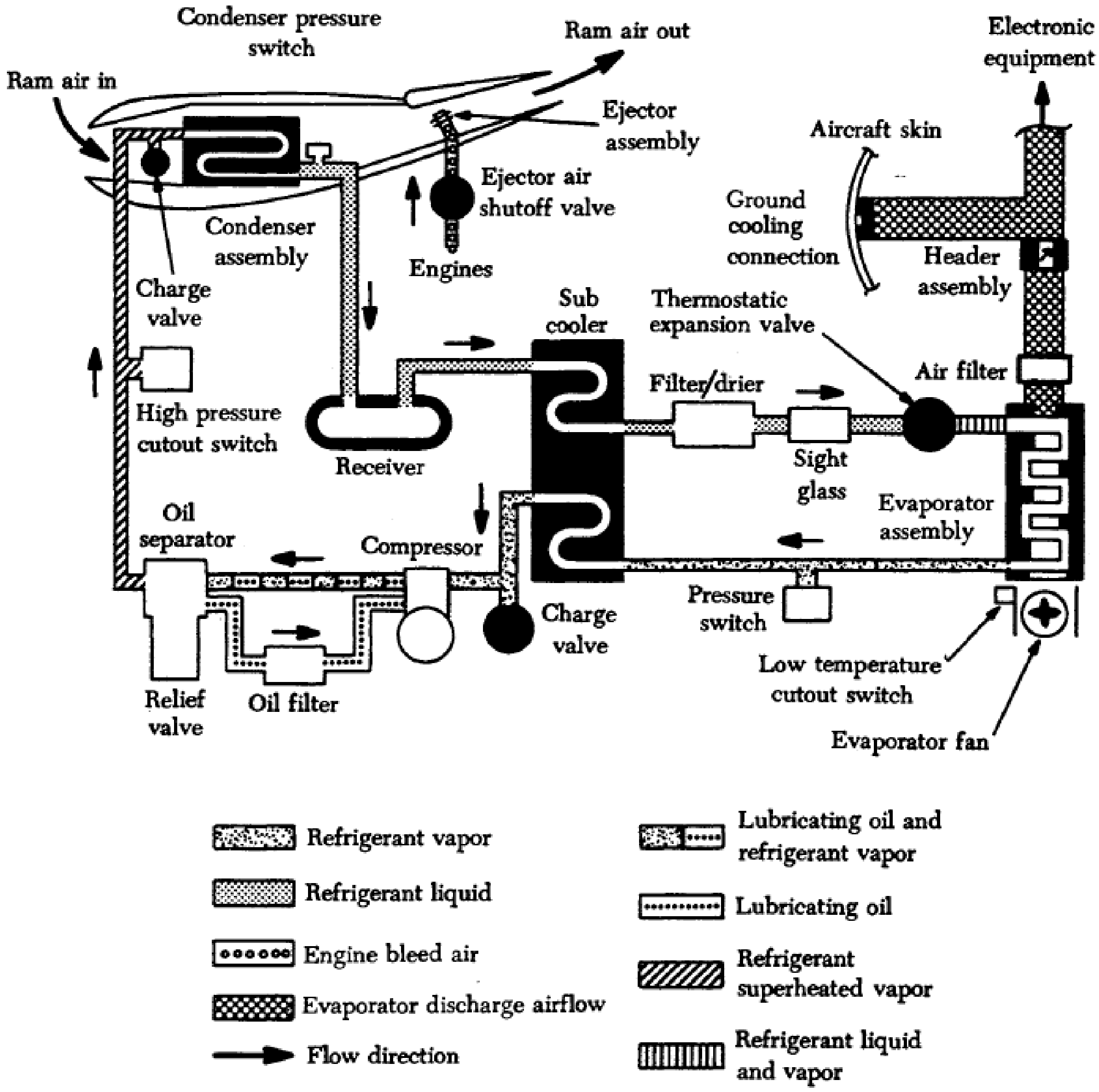


Figure 14-38. Vapor cycle system flow schematic.

Acti

Filter/drier

- It is simply a sheet-metal housing with inlet and outlet connections.
- The housing contains an alumina desiccant, a filter screen, and a filter pad.
- The desiccant absorbs moisture; the screen and filter pad trap any contaminants.

Sight glass

- To help the maintenance technician visually determine if sufficient refrigerant is present.
- It simply permits a view of the fluid passing through the line.

- In normal operation, a steady flow of refrigerant moves past the sight glass.
- If the unit is low on refrigerant, bubbles will be present in the fluid passing the sight glass.

Expansion valve

- Lowers Freon pressure and, thus, Freon temperature.
- The expansion valve meters the flow of refrigerant into the evaporator.
- Metering, or regulation, of the amount of Freon that is sprayed into the evaporator is necessary because the heat load does not remain constant.

Evaporator

- All other system components exist to support the operation of this one component.
- The evaporator is simply a heat exchanger with passages through which warm cabin air flows around passages that contain Freon refrigerant.
- Freon changes in the evaporator from a liquid to a vapor;
- The Freon boils in the evaporator at a temperature lower than the cabin temperature,

The result is that the Freon extracts heat from the cabin air.

Fire protection system

Typical zones on aircraft that have a fixed fire detection and/or fire extinguisher system are:

1. Engines and auxiliary power unit (APU)
2. Cargo and baggage compartments
3. Lavatories on transport aircraft
4. Electronic bays
5. Wheel wells
6. Bleed air ducts

Fires are detected in reciprocating engine and small turboprop aircraft using one or more of the following:

1. Overheat detectors
2. Rate-of-temperature-rise detectors
3. Flame detectors
4. Observation by crewmembers

In addition to these methods, other types of detectors areused in aircraft fire protection systems but are seldom usedto detect engine fires. For example, smoke detectors arebetter suited to monitor areas where materials burn slowlyor smolder, such as cargo and baggage compartments.

Other types of detectors in this category include carbonmonoxide detectors and chemical sampling equipmentcapable of detecting combustible mixtures that can lead toaccumulations of explosive gases.

Fire protection systems of most largeturbine-engine aircraft incorporate several of these different detection methods.

1. Rate-of-temperature-rise detectors
2. Radiation sensing detectors
3. Smoke detectors
4. Overheat detectors
5. Carbon monoxide detectors
6. Combustible mixture detectors
7. Optical detectors
8. Observation of crew or passengers

The types of detectors most commonly used for fast detectionof fires are the rate-of-rise, optical sensor, pneumatic loop,and electric resistance systems.

Classes of Fires

The following classes of fires that are likely to occur onboardaircraft, as defined in the U.S. National Fire ProtectionAssociation (NFPA) Standard 10, Standard for Portable FireExtinguishers, 2007 Edition, are:

1. Class A—fires involving ordinary combustiblematerials, such as wood, cloth, paper, rubber, andplastics.
2. Class B—fires involving flammable liquids, petroleumoils, greases, tars, oil-based paints, lacquers, solvents,alcohols, and flammable gases.
3. Class C—fires involving energized electricalequipment in which the use of an extinguishing mediathat is electrically nonconductive is important.
4. Class D—fires involving combustible metals, suchas magnesium, titanium, zirconium, sodium, lithium,and potassium.

Requirements for Overheat and Fire ProtectionSystems

Fire protection systems on current-production aircraft do notrely on observation by crew members as a primary methodof fire detection. An ideal fire detector system includes asmany of the following features as possible:

1. No false warnings under any flight or groundcondition.
2. Rapid indication of a fire and accurate location of thefire.
3. Accurate indication that a fire is out.
4. Indication that a fire has re-ignited.
5. Continuous indication for duration of a fire.
6. Means for electrically testing the detector system fromthe aircraft cockpit.
7. Resists damage from exposure to oil, water, vibration,extreme temperatures, or handling.
8. Light in weight and easily adaptable to any mountingposition.
9. Circuitry that operates directly from the aircraft powersystem without inverters.
10. Minimum electrical current requirements when notindicating a fire.
11. Cockpit light that illuminates, indicating the locationof the fire, and with an audible alarm system.
12. A separate detector system for each engine.

Fire Detection/Overheat Systems

A fire detection system should signal the presence of a fire.Units of the system are installed in locations where there aregreater possibilities of a fire. Three detector system types incommon use are the thermal switch, thermocouple, and thecontinuous loop.

Thermal Switch System

1. A number of detectors, or sensing devices, are available. Many older-model aircraft still operating have some type of thermal switch system or thermocouple system.
2. A thermal switch system has one or more lights energized by the aircraftpower system and thermal switches that control operation of the light(s).
3. These thermal switches are heat-sensitive units that complete electrical circuits at a certain temperature. They are connected in parallel with each other but in series with the indicator lights.
4. *[Figure 17-1]* If the temperature rises above a set value in any one section of the circuit, the thermal switch closes, completing the light circuit to indicate a fire or overheat condition.
5. No set number of thermal switches is required; the exact number is usually determined by the aircraft manufacturer.
6. On some installations, all the thermal detectors are connected to one light; on others, there may be one thermal switch for each indicator light.
7. Some warning lights are push-to-test lights. The bulb is tested by pushing it in to check an auxiliary test circuit.
8. The circuit shown in *Figure 17-1* includes a test relay. With the relay contact in the position shown, there are two possible paths for current flow from the switches to the light.
9. This is an additional safety feature. Energizing the test relay completes a series circuit and checks all the wiring and the light bulb. Also included in the circuit shown in *Figure 17-1* is a dimming relay.

10. By energizing the dimming relay, the circuit is altered to include a resistor in series with the light. In some installations, several circuits are wired through the dimming relay, and all the warning lights may be dimmed at the same time.

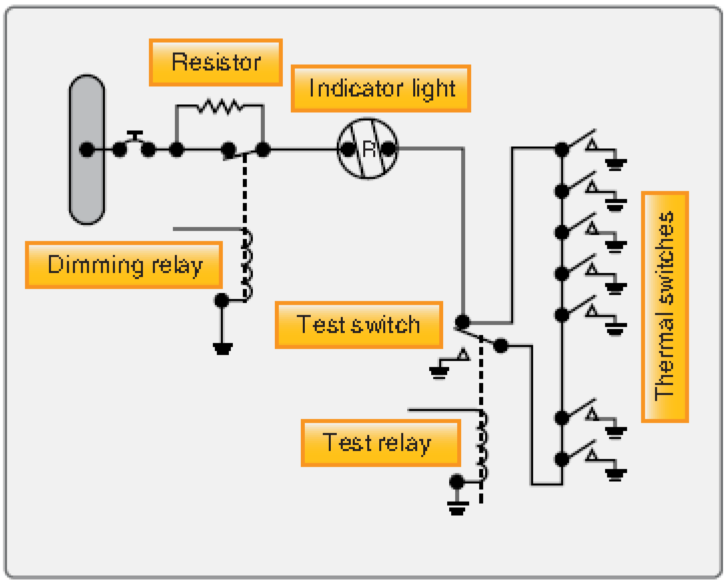


Figure 17-1. *Thermal switch fire circuit.*

Thermocouple System

1. A thermocouple depends on the rate of temperature rise and does not give a warning when an engine slowly overheats or a short circuit develops.
2. The system consists of a relay box, warning lights, and thermocouples. The wiring system of these units may be divided into the following circuits:
    1. Detector circuit
    2. Alarm circuit
    3. Test circuit.
3. These circuits are shown in *Figure 17-2*. The relay box contains two relays, the sensitive relay and the slave relay, and the thermal test unit.
4. Such a box may contain from one to eight identical circuits, depending on the number of potential fire zones.
5. The relays control the warning lights. In turn, the thermocouples control the operation of the relays.
6. The circuit consists of several thermocouples in series with each other andwith the sensitive relay.
7. The thermocouple is constructed of two dissimilar metals, such as chromel and constantan.
8. The point at which these metals are joined and exposed to the heat of a fire is called a hot junction.
9. There is also a reference junction enclosed in a dead air space between two insulation blocks.
10. If the temperature rises rapidly, the thermocouple produces a voltage because of the temperature difference between the reference junction and the hot junction.

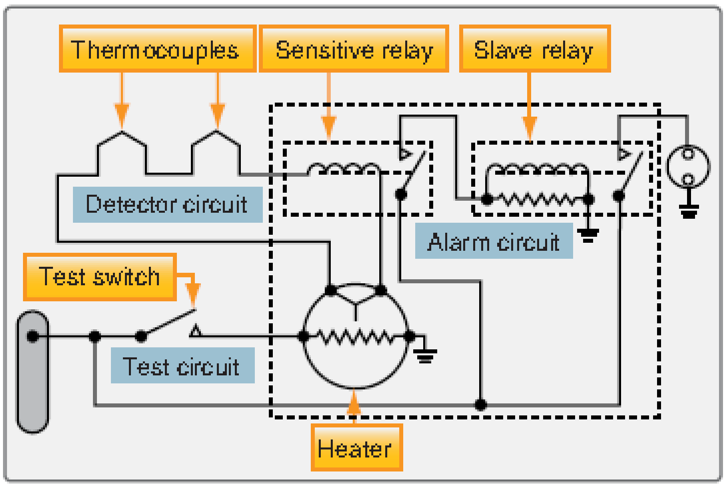


Figure 17-2. *Thermocouple fire warning circuit.*

11. If both junctions are heated at the same rate, no voltage results.
12. In the engine compartment, there is a normal, gradual rise in temperature from engine operation; because it is gradual, both junctions heat at the same rate and no warning signal is given.
13. If there is a fire, however, the hot junction heats more rapidly than the reference junction. The ensuing voltage causes a current to flow within the detector circuit.
14. Any time the current is greater than 4 milliamperes (0.004 ampere), the sensitive relay closes. This completes a circuit from the aircraft power system to the coil of the slave relay.
15. The slave relay then closes and completes the circuit to the warning light to give a visual fire warning.
16. The total number of thermocouples used in individual detector circuits depends on the size of the fire zones and the total circuit resistance, which usually does not exceed 5 ohms.

Continuous-Loop Systems

1. A continuous-loop detector or sensing system permits more complete coverage of a fire hazard area than any of the spot-type temperature detectors.
2. Two widely used types of continuous-loop systems are the thermistor type detectors, such as the Kidde and the Fenwal systems, and the pneumatic pressure detector, such as the Lingberg system. (Lindberg system is also known as Systron-Donner and, more recently, Meggitt Safety Systems.)

Fenwal System

1. The Fenwal system uses a slender Inconel tube packed with thermally sensitive eutectic salt and a nickel wire center conductor. *[Figure 17-3]* Lengths of these sensing elements are connected in series to a control unit.

2. The elements may be of equal or varying length and of the same or different temperature settings. The control unit, operating directly from the power source, impresses a small voltage on the sensing elements.

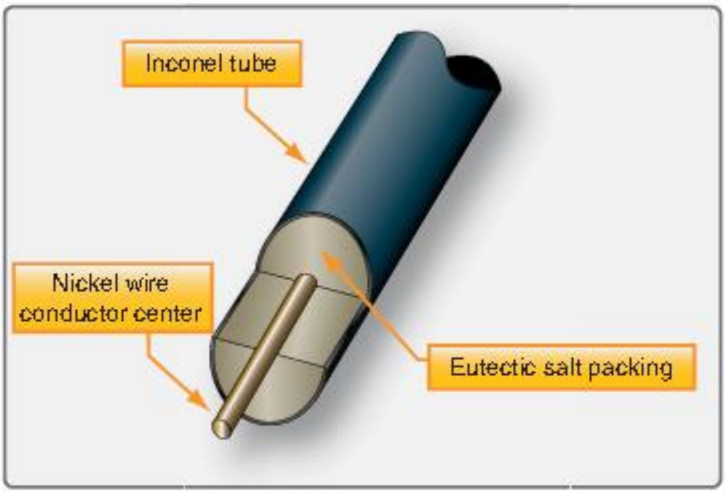


Figure 17-3. *Fenwal sensing element.*

3. When an overheat condition occurs at any point along the element length, the resistance of the eutectic salt within the sensing element drops sharply, causing current to flow between the outer sheath and the center conductor.
4. This current flow is sensed by the control unit, which produces a signal to actuate the output relay and activate the alarms.
5. When the fire has been extinguished or the critical temperature lowered below the set point, the Fenwal system automatically returns to standby alert, ready to detect any subsequent fire or overheat condition.

Kidde System

1. In the Kidde continuous-loop system, two wires are imbedded in an inconel tube filled with a thermistor core material. *[Figure 17-4]*
2. Two electrical conductors go through the length of the core. One conductor has a ground connection to the tube, and the other conductor connects to the fire detection control unit.
3. As the temperature of the core increases, electrical resistance to the ground decreases. The fire detection control unit monitors this resistance.
4. If the resistance decreases to the overheat set point, an overheat indication occurs in the flight deck. Typically, a 10-second time delay is incorporated for the overheat indication.
5. If the resistance decreases more to the fire set point, a fire warning occurs.
6. When the fire or overheat condition is gone, the resistance of the core material increases to the reset point and the flight deck indications disappear.
7. The rate of change of resistance identifies an electrical short or a fire.
8. The resistance decreases more quickly with an electrical short than with a fire.
9. In some aircraft, in addition to fire and overheat detection, the Kidde continuous-loop system can supply nacelle temperature data to the airplane condition monitoring function of the aircraft in-flight monitoring system (AIMS).

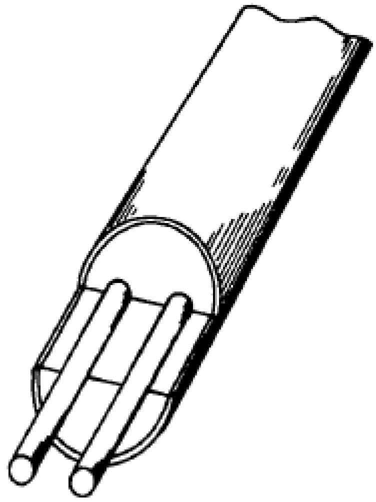


FIGURE 10–5. Kidde sensing element.

SMOKE DETECTION SYSTEMS -

A smoke detection system monitors the cargo andbaggage compartments for the presence of smoke,which is indicative of a fire condition. Smoke detection-instruments, which collect air for sampling, aremounted in the compartments in strategic locations.

Smoke detection instruments are classified bymethod of detection as follows:

Type I – Measurementof carbon monoxide gas (CO detectors),

TypeII - Measurement of light transmissibility in air(photoelectric devices) , and

Type III - Visual detectionof the presence of smoke by directly viewingair samples (visual devices) •

Carbon Monoxide Detectors

1. The CO detectors, which detect concentrations of carbon monoxide gas, are rarely used to monitor cargo and baggage compartments.
2. However, they have gained widespread use in conducting tests for the presence of carbon monoxide gas in aircraft cabins and cockpits.
3. Carbon monoxide is a colorless, odorless, tasteless, non-irritating gas. It is the byproduct of incomplete combustion, and is found in varying degrees in all smoke and fumes from burning carbonaceous substances.
4. A concentration of .02% (2 parts in 10,000) may produce headache, mental dullness, and physical loginess within a few hours.
5. There are several types of portable testers (sniffers) in use. One type has a replaceable indicator tube which contains a yellow silica gel, impregnated with a complex silico-molybdate compound and is catalyzed using palladium sulfate.
6. In use, a sample of air is drawn through the detector tube.
7. When the air sample contains carbon monoxide, the yellow silica gel turns to a shade of green.

8. The intensity of the green color is proportional to the concentration of carbon monoxide in the air sample at the time and location of the tests.

The maximum allowable concentration under Federal Law for continuing exposure is 50 ppm (parts per million) which is equal to 0.005% of carbon monoxide.

Parts Per Million	Percentage	Reaction
50	0.005%	Maximum allowable concentration under Federal Law.
100	0.01 %	Tiredness, mild dizziness.
200	0.02 %	Headaches, tiredness, dizziness, nausea after 2 or 3 hours.
800	0.08 %	Unconsciousness in 1 hour and death in 2 to 3 hours.
2,000	0.20 %	Death after 1 hour.
3,000	0.30 %	Death within 30 minutes.
10,000	1.00 %	Instantaneous death.

FIGURE 10–31. Human reactions to carbon monoxide poisoning.

Photoelectric Smoke Detectors

1. This type of detector consists of a photoelectric cell, a beacon lamp, a test lamp, and a light trap, all mounted on a labyrinth.
2. An accumulation of 10% smoke in the air causes the photoelectric cell to conduct electric current.
3. When activated by smoke, the detector supplies a signal to the smoke detector amplifier. The amplifier signal activates a warning light and bell.

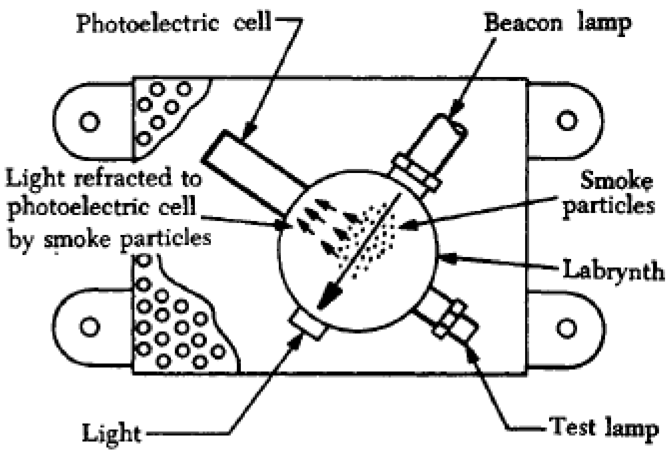


FIGURE 10–29. Photoelectric smoke detector.

Visual Smoke Detectors

1. On a few aircraft visual smoke detectors provide the only means of smoke detection.

2. Indication is provided by drawing smoke through a line into the indicator, using either a suitable suction device or cabin pressurization.
3. When smoke is present a lamp within the indicator is illuminated automatically by the smoke detector.
4. The light is scattered so that the smoke is rendered visible in the appropriate window of the indicator.
5. If no smoke is present the lamp will not be illuminated. A switch is provided to illuminate the lamp for test purposes.

Pneumatic Deicing System

1. In this system, air pressure for system operation is supplied by air bled from the engine compressor.
2. The bleed air from the compressor is ducted to a pressure regulator.
3. **The regulator** reduces the pressure of the turbine bleed air to the deicer system pressure.
4. **An ejector** provides the vacuum necessary to keep the boots deflated.
5. **The air pressure and suction relief valves and regulators** maintain the pneumatic system pressure and suction at the desired settings.
6. **The timer** is essentially a series of switch circuits actuated successively by a solenoid-operated rotating step switch.
7. **The timer** is energized when the deicing switch is placed in the "on" position.
8. When the system is operated, the deicer port in the distributor valve is closed to vacuum and system operating pressure is applied to the deicers connected to that port.
9. At the end of the inflation period the deicer pressure port is shut off, and air in the deicer flows overboard through the exhaust port.
10. When the air flowing from the deicers reaches a low pressure (approximately 1 p.s.i.) , the exhaust port is closed.
11. Vacuum is re-applied to exhaust the remaining air from the deicer.
12. This cycle is repeated as long as the system is operating. If the system is turned off, the system timer automatically returns to its starting position.

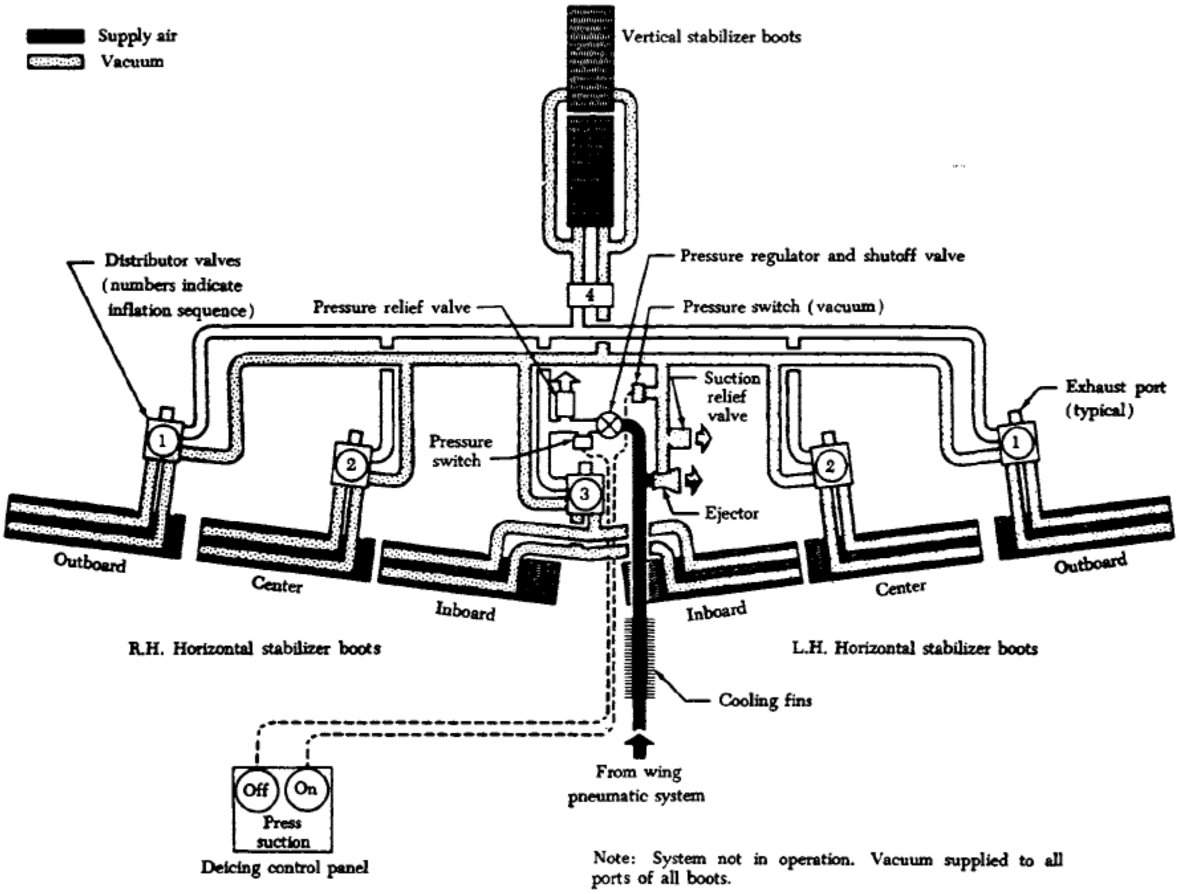


FIGURE 7–4. Schematic of a pneumatic deicing system.

Anti-Icing Using Combustion Heaters

1. Anti-icing systems using combustion heaters usually have a separate system for each wing and the empennage.
2. A typical system of this type has the required number of· combustion heaters located in each wing and in the empennage.
3. A system of ducting and valves controls the airflow.
4. The anti-icing system is automatically controlled by overheat switches, thermal cycling switches, a balance control, and a duct pressure safety switch.
5. The overheat and cycling switches allow the heaters to operate at periodic intervals, and they also stop heater operation completely if overheating occurs.
6. The balance control is used to maintain equal heating in both wings.
7. The duct pressure safety switch interrupts the heater ignition circuits if ram air pressure falls below a specified amount.

8. This protects the heaters from overheating when not enough ram air is passing through.

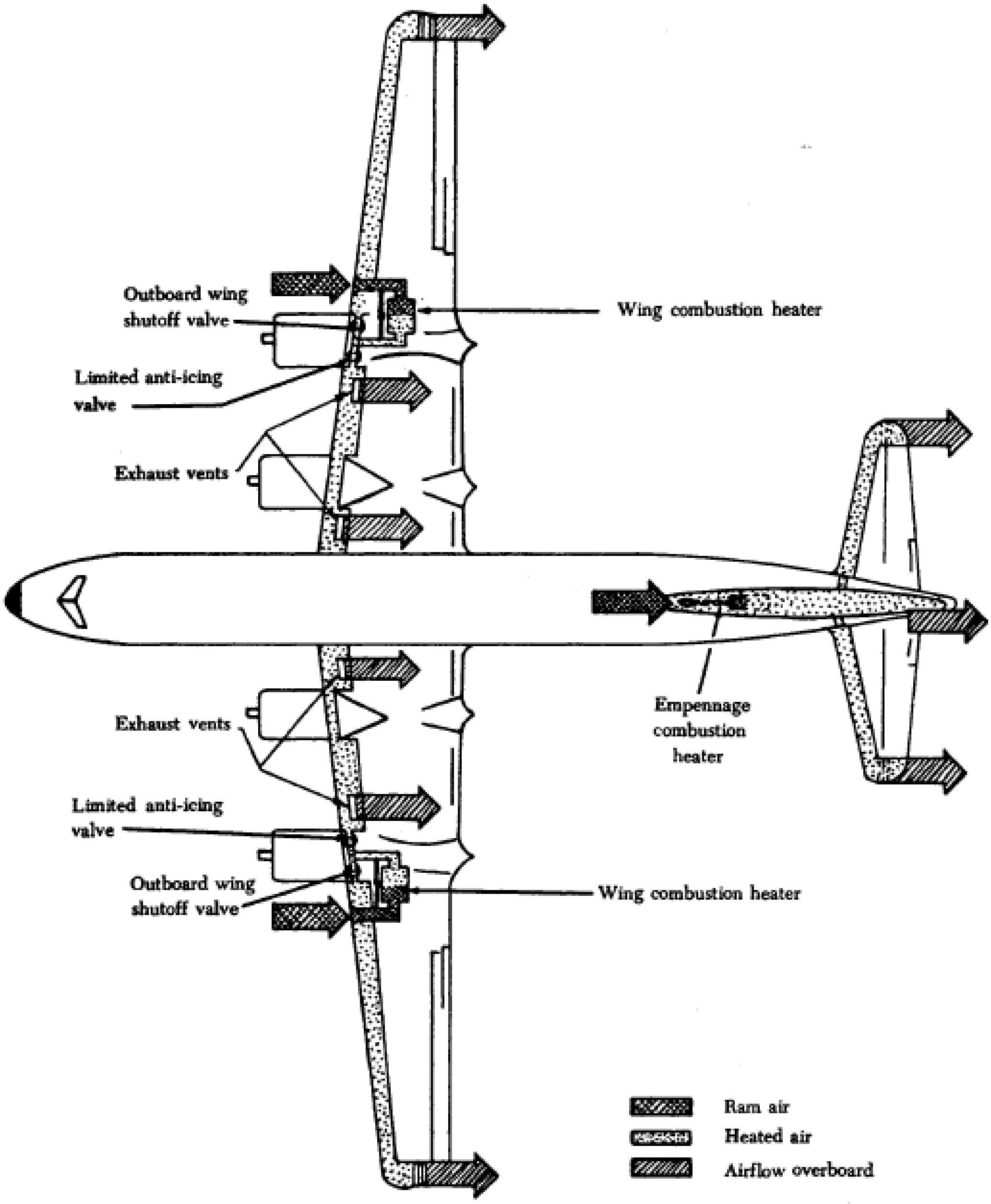


FIGURE 7-9. Airflow diagram of a typical anti-icing system.

Anti-Icing Using Exhaust Heaters

1. Note that, normally, the wing and tail anti-icing system is controlled electrically by operating the heat anti-ice button.
2. When the button is in the "off" position, the outboard heat source valves and the tail anti-ice valve are closed.
3. While the anti-ice system is off, the inboard heat source valves are controlled by the cabin temperature control system.
4. Furthermore the augmentor vanes can he controlled by the augmentor vane switch.

5. Pushing the heat anti-ice button to the "on" position opens the heat source valves and the tail antiicing valve.
6. A holding coil keeps the button in the "on" position. In addition, the augmentor vane control circuits are automatically armed.
7. The vanes can be closed by positioning the augmentor vane switch to "close." This provides for maximum heat from the system.
8. A safety circuit controlled by thermostatic limit switches (not shown) in the anti-icing system ducts, releases the anti-ice button to the "off" position whenever a duct becomes overheated.
9. When overheating occurs, the heat source valves and the tail anti-icing shutoff valve close and the augmentor vanes go to the trail (open) position.
10. The heat source valves can be closed manually by the manual heat anti-ice shutoff handle. Manual operation may be necessary if the electrical control circuits for the valves fail.
11. In this system, the handle is connected to the valves by a cable system and clutch mechanism.
12. Once the heat source valves have been operated manually, they cannot be operated electrically until the manual override system is re-set. Most systems provide for re-setting of the manual override system in flight.

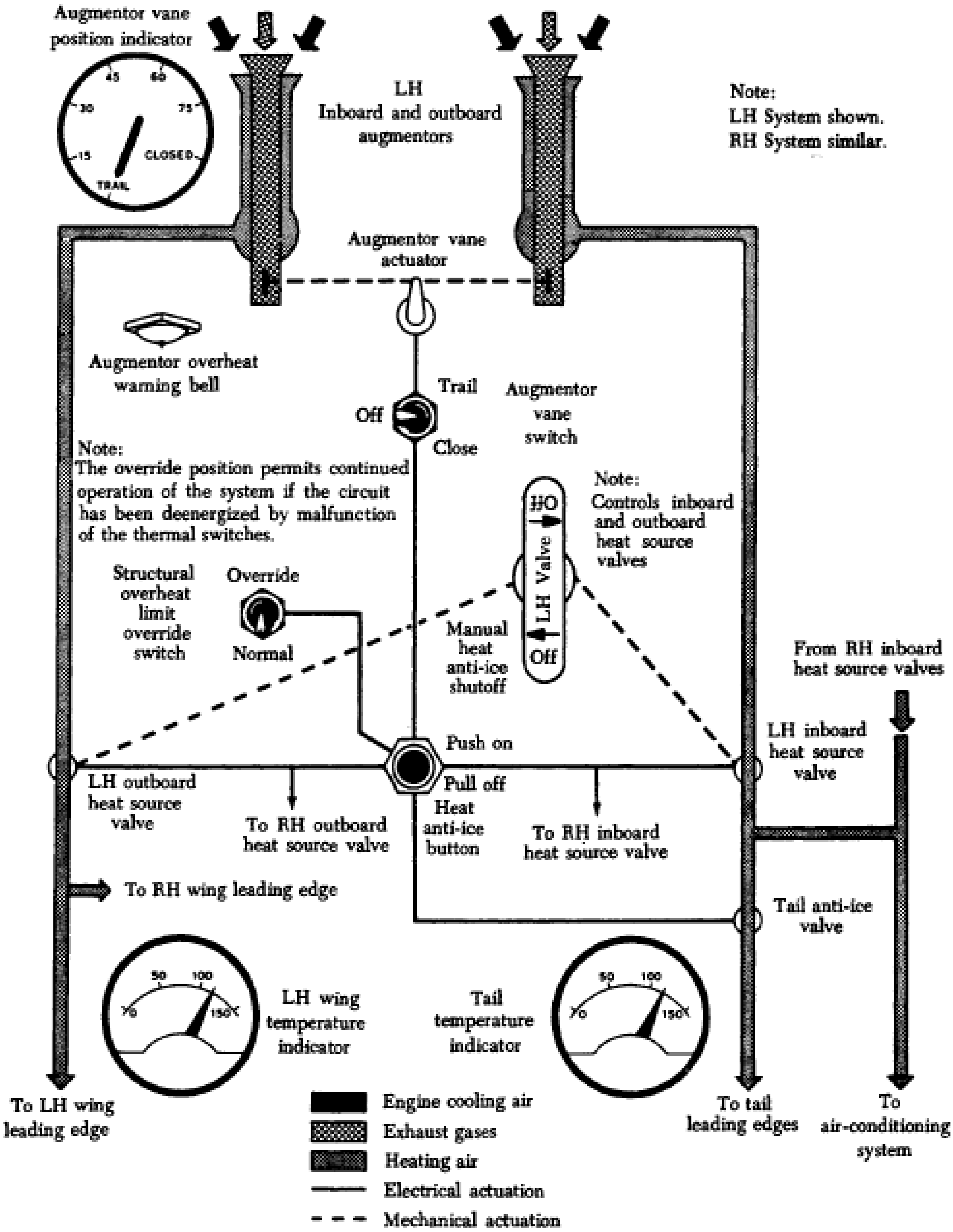


FIGURE 7-11. Wing and tail anti-icing system schematic.

THERMAL ANTIICING

1. Air for anti-icing is obtained by bleeding air from the engine compressor.
2. The reason for the use of such a system is that relatively large amounts of very hot air can be tapped of the compressor, providing a satisfactory source of anti-icing and deicing heat.
3. This system is divided into six sections. Each section includes (1) a shutoff valve, (2) a temperature indicator, and (3) an overheat warning light
4. **The shutoff valve** for each anti-icing section is a pressure regulating type.
5. **The valve** controls the flow of air from the bleed air system to the ejectors
6. The hot bleed air is mixed with ambient air.
7. The resultant mixed air at approximately 350° F. flows through passages next to the leading edge skin.
8. **Each of the shutoff valves** is pneumatically actuated and electrically controlled.
9. **Each shutoff valve** acts to stop anti-icing and to control airflow when anti-icing is required.
10. **A thermal switch** connected to the control solenoid of the shutoff valve causes the valve to close and shutoff the flow of bleed air when the temperature in the leading edge reaches approximately 185 ° F.
11. When the temperature drops, the valve opens, and hot bleed air enters the leading edge.
12. **The temperature indicator** for each anti-icing section is located on the anti-icing control panel each indicator is connected to a resistance-type temperature bulb located in the leading edge area.
13. **The temperature bulb** is placed so that it senses the temperature of the air in the area aft of the leading edge skin, not the hot air passed next to the akin.
14. **Overheat warning systems** are provided to protect the aircraft structure from damage due to excessive heat.
15. If the normal cyclic system fails, temperature sensors operate to open the circuit controlling the anti-ice shutoff valves. The valves close pneumatically to shut off the flow of hot air.

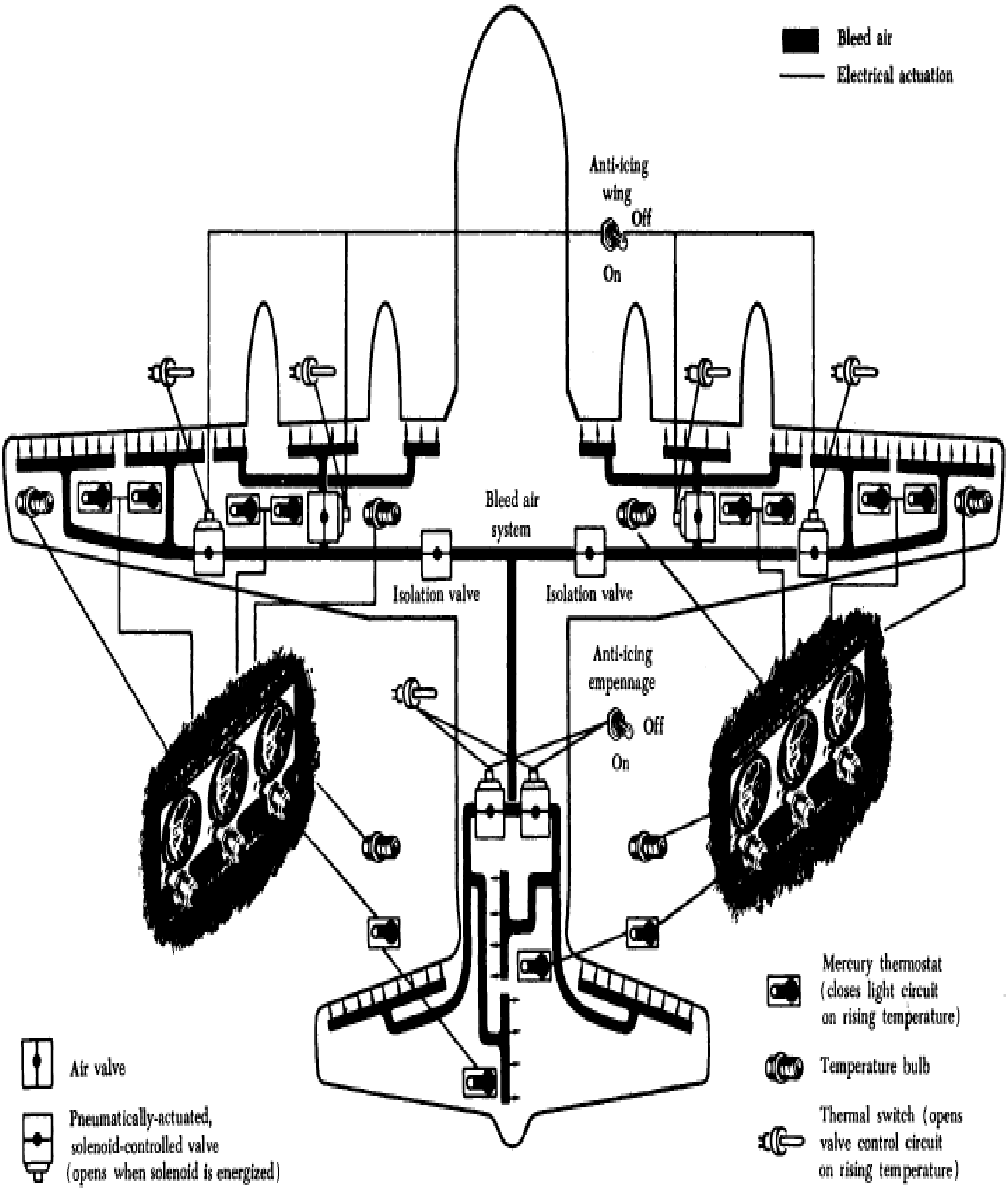


FIGURE 7-12. Schematic of a typical thermal anti-icing system.

UNIT V

FLIGHT INSTRUMENTS

1. The instruments used in controlling the aircraft's flight attitude are known as the flight instruments.
2. There are basic flight instruments, such as the altimeter that displays aircraft altitude; the airspeed indicator; and the magnetic direction indicator, a form of compass. Additionally,

an artificial horizon, turn coordinator, and vertical speed indicator are flight instruments present in most aircraft.

3. This basic T arrangement for flight instruments is shown in *Figure 10-4.* The top center position directly in front of the pilot and copilot is the basic display position for the artificial horizon even in modern glass cockpits (those with solid-state, flat-panel screen indicating systems).

4. Original analog flight instruments are operated by air pressure and the use of gyroscopes.

ENGINE INSTRUMENTS

1 Engine instruments are those designed to measure operating parameters of the aircraft's engine(s).

2 These are usually quantity, pressure, and temperature indications. They also include measuring engine speed(s).

3 The most common engine instruments are the fuel and oil quantity and pressure gauges, tachometers, and temperature gauges.

NAVIGATION INSTRUMENTS

1. Navigation instruments are those that contribute information used by the pilot to guide the aircraft along a definite course.
2. This group includes compasses of various kinds, some of which incorporate the use of radio signals to define a specific course while flying the aircraft en route from one airport to another.
3. Other navigational instruments are designed specifically to direct the pilot's approach to landing at an airport.
4. Traditional navigation instruments include a clock and a magnetic compass.
5. Radios and instruments sending locating information via radio waves have replaced these manual efforts in modern aircraft.

THE GYROSCOPE AND ITS PROPERTIES

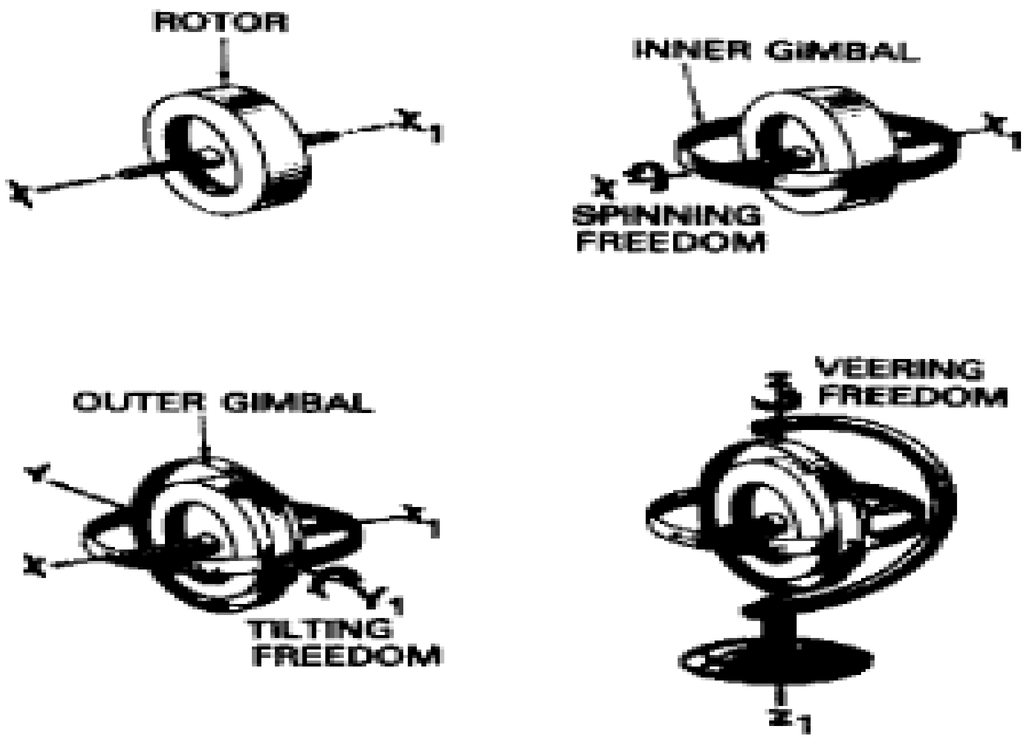
Definition:

As a mechanical device a gyroscope may be defined as a system containing a heavy metal wheel, or rotor, universally mounted so that it has three degrees of freedom:

(i) Spinning freedom about an axis perpendicular through its centre (axis of spin XX,);

(ii) Tiltingfreedom about a horizontal axis at right angles to the spin axis (axis of tilt YY,); and (iii) veering freedom about a vertical axis perpendicular to both the spin and tilt axes (axis of veer ZZ,).

1. The three degrees of freedom are obtained by mounting the rotor in two concentricalIy pivoted rings, called inner and outer gimbal rings. The whole assembly is known as the gimbal system of a **free or space gyroscope**.
2. The system will not exhibit gyroscopic properties unless the rotor is spinning; for example, if a weight is hung on the inner gimbal **ring,** it will merely displace the rings about axis **YY,** because there is no resistance to the weight.
3. When the rotor is made to spin at high speed the device then becomes a true gyroscope possessing two important fundamental properties: ***gyroscopic inertia*** or ***rigidity,*** and ***precession.***
4. If a weight is now hung on the inner gimbal ring with the rotor running, it will be found that the gimbal ring will support the weight, thus demonstrating the first fundamental property of rigidity.
5. However, it will also be found that the complete gimbal system will start rotating about the axis ZZ, such rotation demonstrating the second property of precession. Figure *5.2* illustrates how gyroscopic rigidity may be demonstrated.
6. If the frame and outer gimbal ring are tipped about the axis YY, the gyroscope maintains its spin axis in the horizontal position. If the frame is either rotated about the axis **ZZ,** or is swung in an arc, the spin axis will continue to point in the same direction.



The two properties of gyroscope:

Rigidity

The property which resists any force tending to change the plane of rotation of its rotor. This property is dependent on three factors: (i) the mass of the rotor, (ii) the speed of rotation,
and (iii) the distance at which the mass acts from the centre, i.e. the radius of gyration.

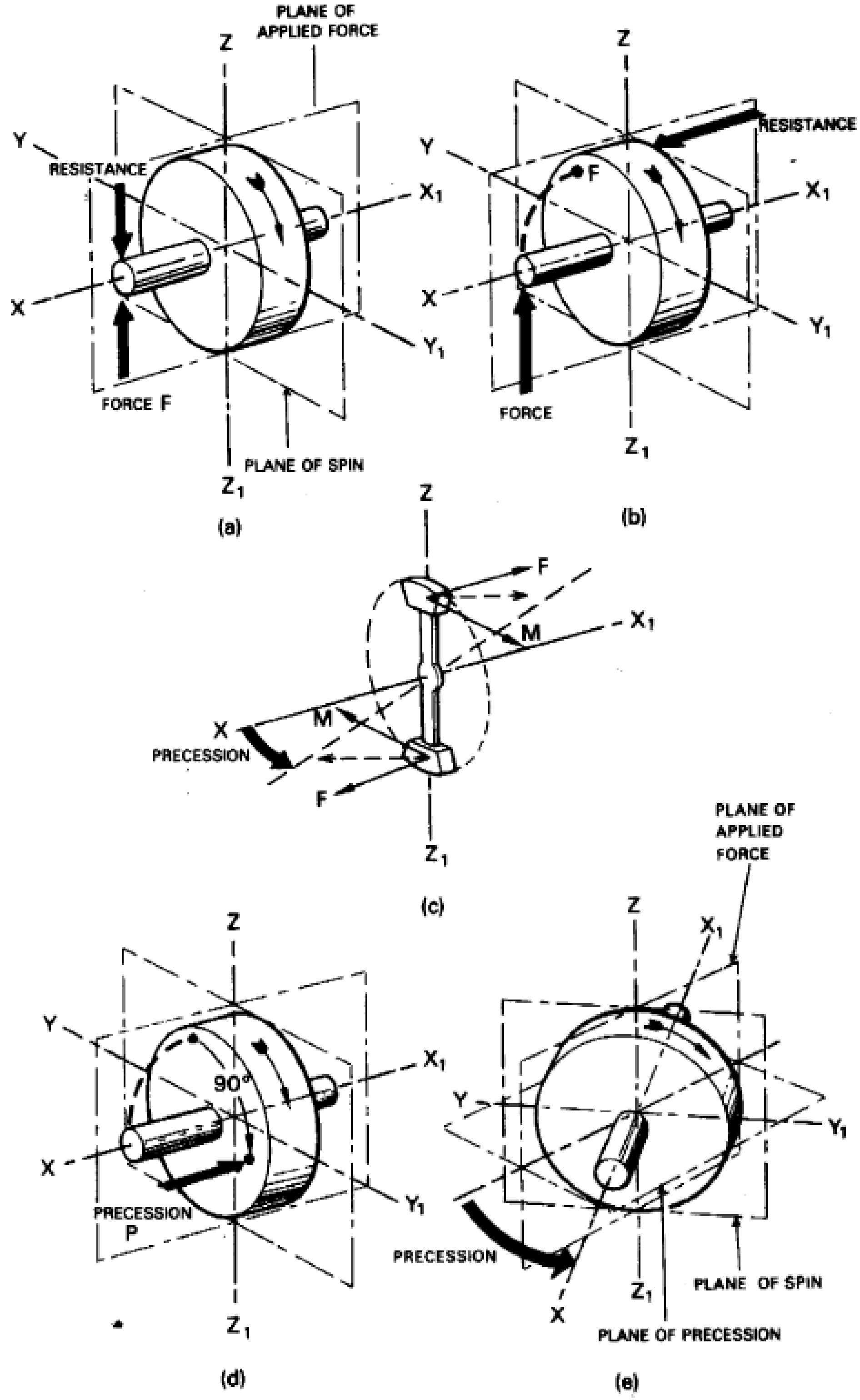
Precession

The angular change in direction of the plane of rotation under the influence of an applied force. The change in direction takes place, not in line with the applied force, but always at a point ***90'*** away in the direction of rotation. The rate of precession also depends on three factors: (i) the strength and direction of the applied force, (ii) the moment of inertia of the rotor, and **(iii)** the angular velocity of the rotor. The greater the force, the greater is the rate of precession, while the greater the moment of inertia and the greater the angular velocity, the smaller is the rate of precession.

The axis about which a torque is applied is termed the ***input*** axis, and the one about which precession takes place in termed the output ***axis.***

Determining the Direction of Precession:

1. At (a) in Fig 5.3, the rotor of a gyroscope is shown spinning in a clockwise direction and with a **force F, applied on the inner gimbal ring**.
2. In transmitting this force to the rim of the rotor, as will be noted from (b), it will act in a horizontal direction.
3. Let us imagine for a moment that the rotor is broken into segments and concern ourselves with two of them at opposite sides of the rim as show at *(c)*.
4. Each segment has motion m in the direction of rotor spin, so that when the force F is applied there is a tendency for each segment to move in the direction of the force.
5. As the gyroscope possesses rigidity this motion is resisted, but the segments will turn about the axis ZZ, so that their direction of motion is along the resultant of motion m and force F.
6. The other segments will be affected in the same way; therefore, when they are all joined to form the solid mass of the rotor it will precess at an angular velocity proportional to the applied force (see diagrams (d) and (e)).'


PLANE OF
APPLIED FORCE
Z
Y
RESISTANCE
X₁
X
Y₁
FORCE F
PLANE OF SPIN
Z₁
(a)
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Y
F
X₁
X
Y₁
FORCE
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(b)
Z
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M
X₁
M
X
PRECESSION
F
Z₁
(c)
PLANE OF
APPLIED
FORCE
Z
Y
90°
X₁
X
PRECESSION
P
Y₁
Z₁
(d)
Z
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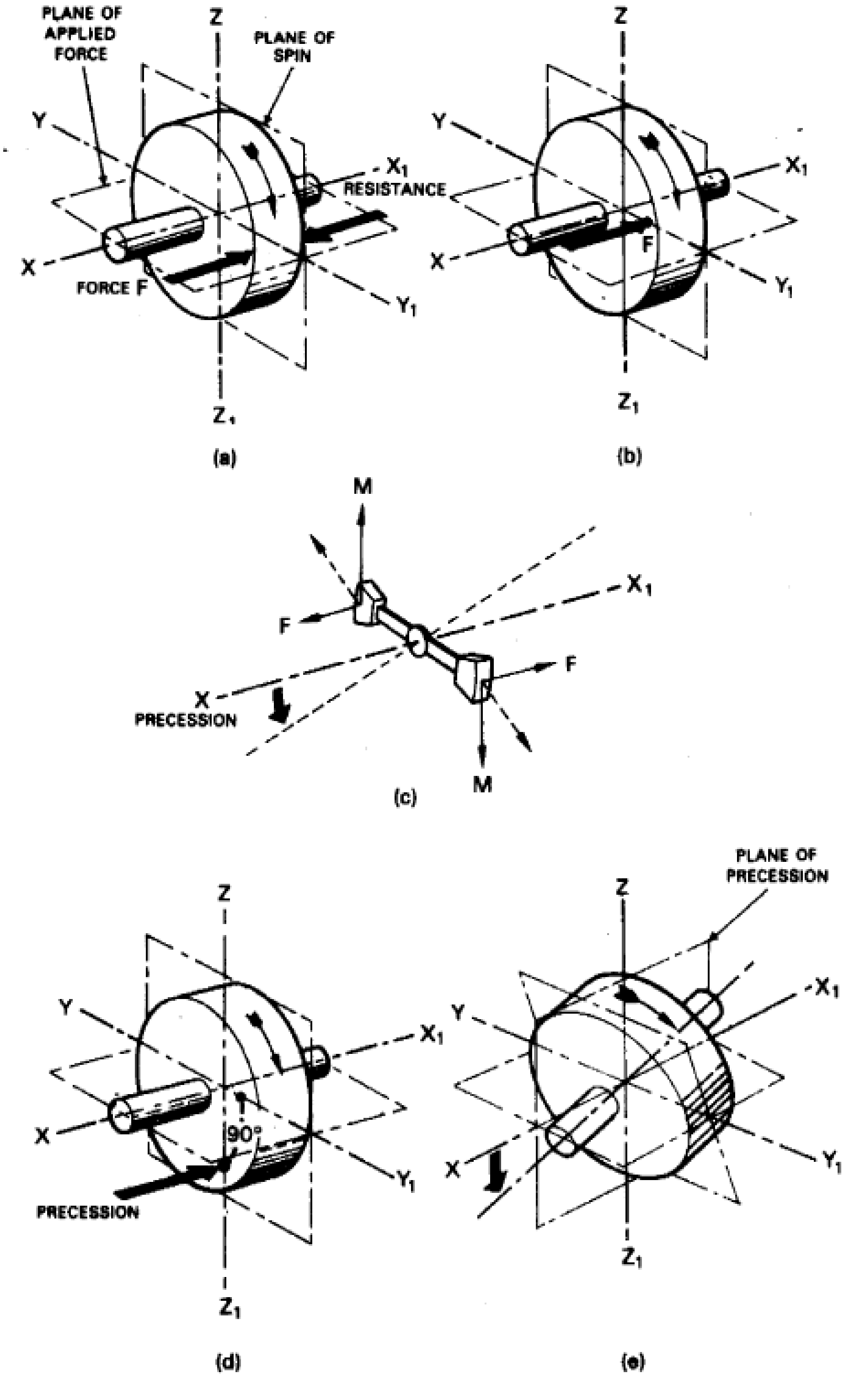
X
Z₁
PLANE OF SPIN
PLANE OF PRECESSION
(e)

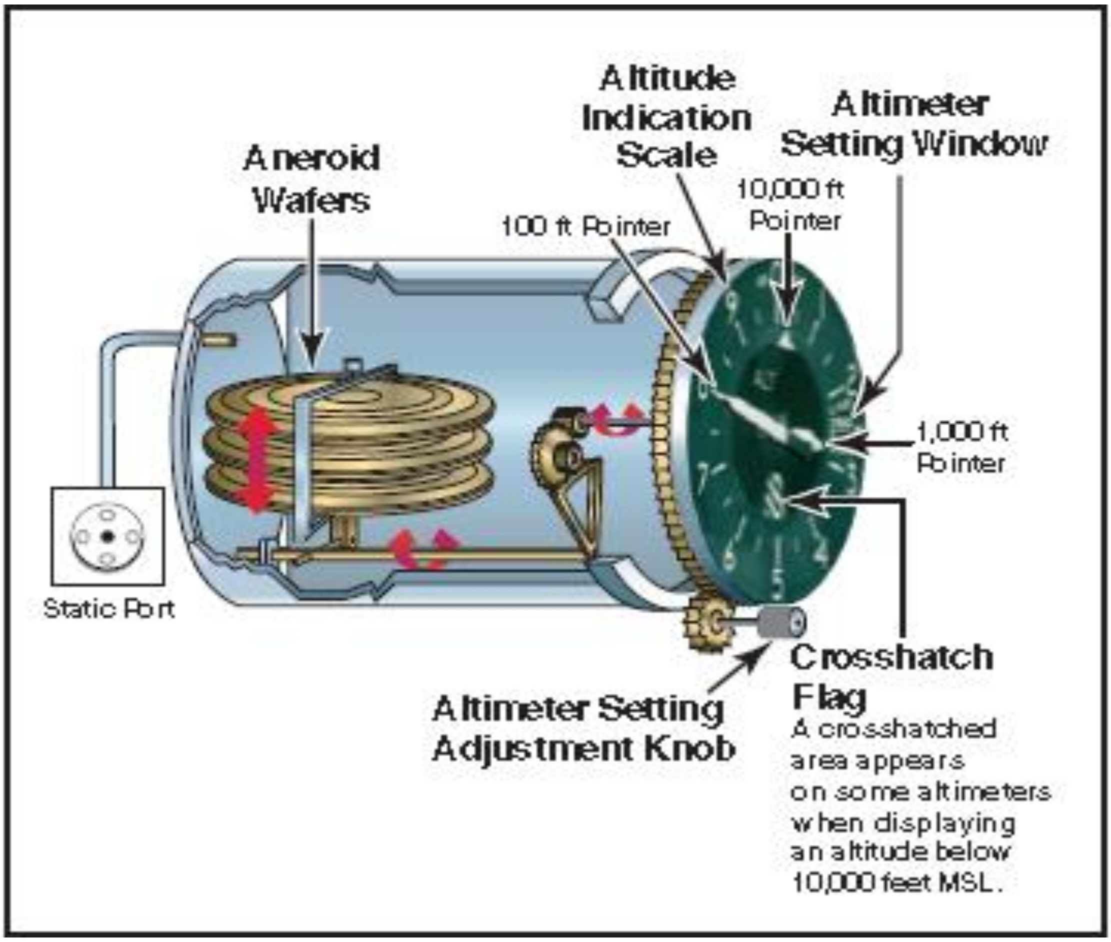


In the example illustrated in Fig. 5.4 (a), a 'force, F, is shown **applied on the outer ring**;

1. This is the same as transmitting the force on the rotor rim at the point shown in diagram (b).
2. As in the previous example this results in the direction of motion changing to the resultant of motion m and force F,
3. This time, however, the rotor precesses about the axis YY, as indicated at (d) and *(e)*.

ALTIMETER

1. The altimeter measures the height of the airplane above a given pressure level. Since it is the only instrument that gives altitude information.
2. A stack of sealed **aneroid** wafers comprises the main component of the altimeter. These wafers expand and contract with changes in atmospheric pressure from the static source.
3. The mechanical linkage translates these changes into pointer movements on the indicator. [Figure 6-2]



PRINCIPLE OF OPERATION

4. The pressure altimeter is an aneroid barometer that measures the pressure of the atmosphere at the level where the altimeter is located, and presents an altitude indication in feet.
5. The altimeter uses static pressure as its source of operation. Air is denser at sea level than aloft, so as altitude increases, atmospheric pressure decreases.
6. This difference in pressure at various levels causes the altimeter to indicate changes in altitude.
7. Some have one pointer while others have two or more.
8. The dial of a typical altimeter is graduated with numerals arranged clockwise from 0 to 9.

9. Movement of the aneroid element is transmitted through gears to the three hands that indicate altitude.
10. The **shortest hand** indicates altitude in tens of thousands of feet; the **intermediate hand** in thousands of feet; and the **longest hand** in hundreds of feet.
11. This indicated altitude is correct, however, only when the sea level barometric pressure is standard (29.92 inches of mercury), the sea level free air temperature is standard (+15°C or 59°F), and the pressure and temperature decrease at a standard rate with an increase in altitude.

ACCELEROMETERS

1. An accelerometer is an instrument that measures acceleration. It is used to monitor the forces acting upon an airframe.
2. Accelerometers are also used in inertial reference navigation systems. The installation of accelerometers is usually limited to high-performance and aerobatic aircraft.
3. Simple accelerometers are mechanical, direct-reading instruments calibrated to indicate force in Gs. One G is equal to one times the force of gravity.
4. The dial face of an accelerometer is scaled to show positive and negative forces.
5. When an aircraft initiates a rapid climb, positive G force tends to push one back into one's seat. Initiating a rapid decent causes a force in the opposite direction, resulting in a negative G force.
6. Most accelerometers have three pointers.
7. One is continuously indicating the acceleration force experienced.
8. The other two contain ratcheting devices.
9. The positive G pointer follows the continuous pointer and stay at the location on the dial where the maximum positive force is indicated.
10. The negative G pointer does the same for negative forces experienced.
11. Both max force pointers can be reset with a knob on the instrument face. The accelerometer operates on the principle of inertia. A mass, or weight, inside is free to slide along a shaft in response to the slightest acceleration force.

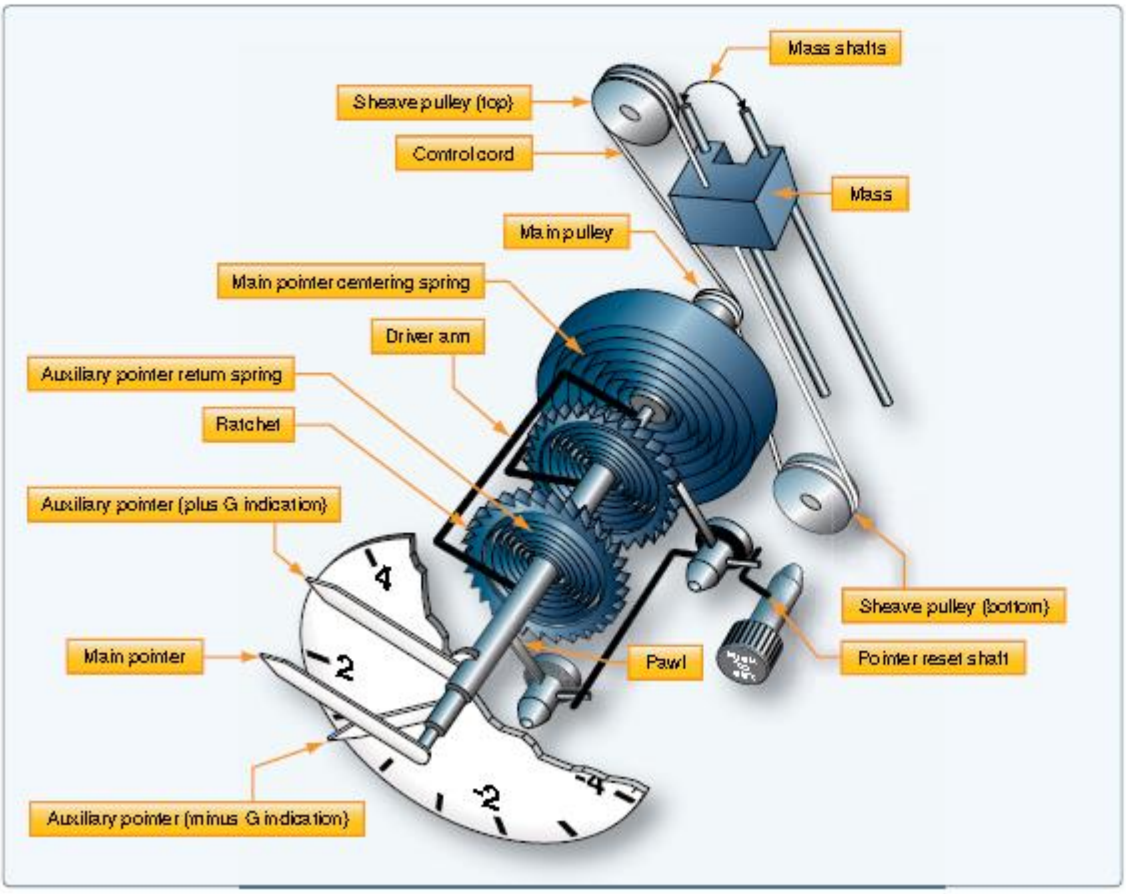
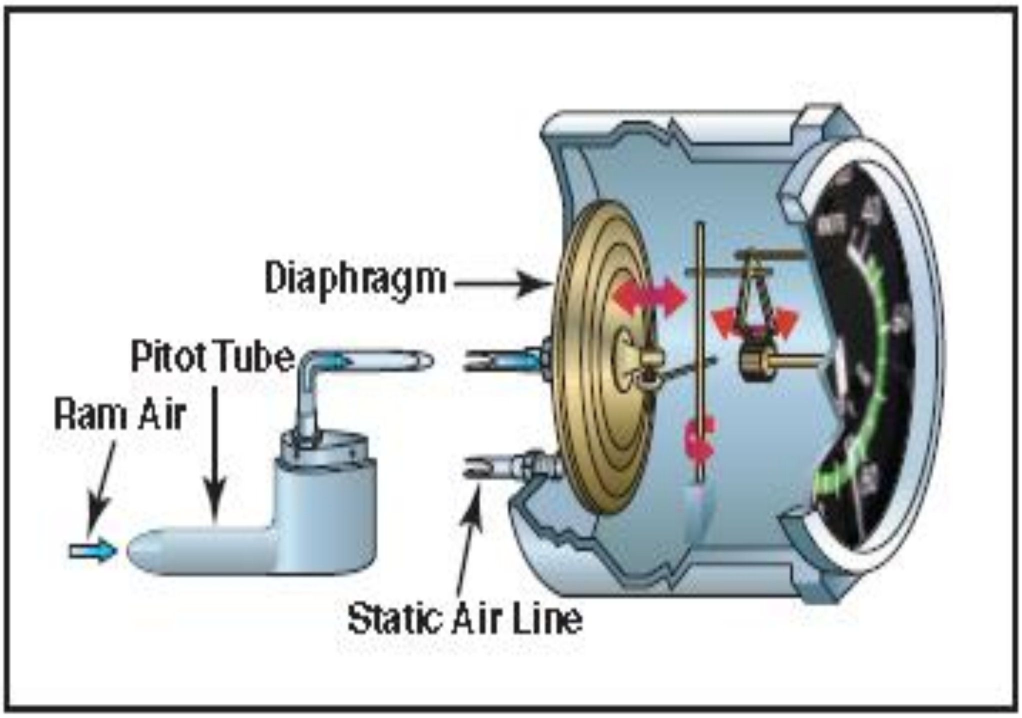


Figure 10-60. *The inner workings of a mass-type accelerometer.*

AIRSPEED INDICATOR

1. The airspeed indicator is a sensitive, differential pressure gauge which measures and shows promptly the difference between pitot or impact pressure, and static pressure, the undisturbed atmospheric pressure at level flight.
2. These two pressures will be equal when the airplane is parked on the ground in calm air.
3. When the airplane moves through the air, the pressure on the pitot line becomes greater than the pressure in the static lines.
4. This difference in pressure is registered by the airspeed pointer on the face of the instrument, which is calibrated in miles per hour, **knots**, or both.



Pilots should understand the following speeds:

Indicated Airspeed (IAS)—The direct instrument reading obtained from the airspeed indicator, uncorrected for variations in atmospheric density, installation error, or instrument error.

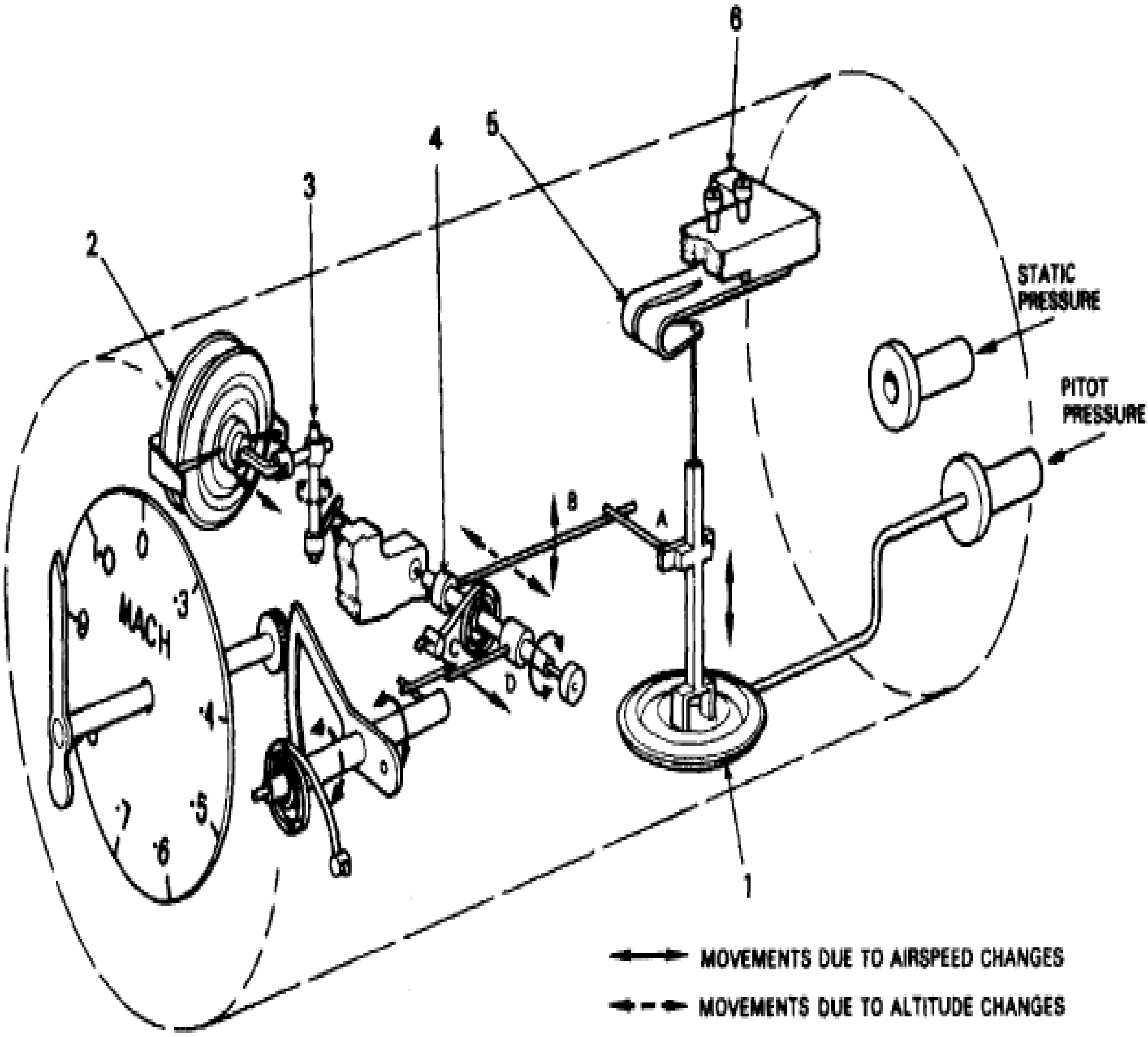
Calibrated Airspeed (CAS)—Indicated airspeed corrected for installation error and instrument error. Although manufacturers attempt to keep airspeed errors to a minimum, it is not possible to eliminate all errors throughout the airspeed operating range.

True Airspeed (TAS)—Calibrated airspeed corrected for altitude and nonstandard temperature. Because air density decreases with an increase in altitude, an airplane has to be flown faster at higher altitudes to cause the same pressure difference between pitot impact pressure and static pressure.

Groundspeed (GS)—The actual speed of the airplane over the ground. It is true airspeed adjusted for wind. Groundspeed decreases with a headwind, and increases with a tailwind.

Machmeter

1. A Mach meter is a compound flight instrument which accepts **two** variables and uses them to compute the required ratio.
2. The first variable is airspeed and therefore a mechanism based on the conventional **airspeed** indicator is **adopted** to **measure** this in terms of the pressure difference p **- s,** where p is the total or **pitot** pressure and **s** the static pressure.
3. The second variable is altitude, and this is also meas'ured in the conventional manner, i.e. by means of an aneroid capsule sensitive to the static pressure **S.**
4. Deflections of the capsules of both mechanisms are transmitted to the indicator pointer by rocking shafts and levers, the dividing function of the altitude unit being accomplished by an intermediate sliding rocking shaft.



Tachometers

1. The tachometer, or tach, is an instrument that indicates thespeed of the crankshaft of a reciprocating engine.
2. Onreciprocating engines, the tach is used to monitor engine powerand to ensure the engine is operated within certified limits.
3. Gas turbine engines also have tachometers. They are usedto monitor the speed(s) of the compressor section(s) ofthe engine.
4. Turbine engine tachometers are calibratedin percentage of rpm with 100 percent corresponding tooptimum turbine speed.
5. There are two types of tachometersystem in wide use today: mechanical and electrical.

Mechanical Tachometers

1. Mechanical tachometer indicating systems are found on small,single-engine light aircraft.
2. They consistof an indicator connected to the engine by a flexible driveshaft.
3. The drive shaft is geared into the engine so that whenthe engine turns, so does the shaft.
4. The indicator contains aflyweight assembly coupled to a gear mechanism that drivesa pointer.

5. As the drive shaft rotates, centrifugal force actson the flyweights and moves them to an angular position.
6. This angular position varies with the rpm of the engine.
7. Theamount of movement of the flyweights is transmitted throughthe gear mechanism to the pointer.
8. The pointer rotates toindicate this movement on the tachometer indicator, whichis directly related to the rpm of the engine. *[Figure 10-53]*

Figure 10-52. *Atachometer for a reciprocating engine is calibrated in rpm. Atachometer for a turbine engine is calculated in percent of rpm.*

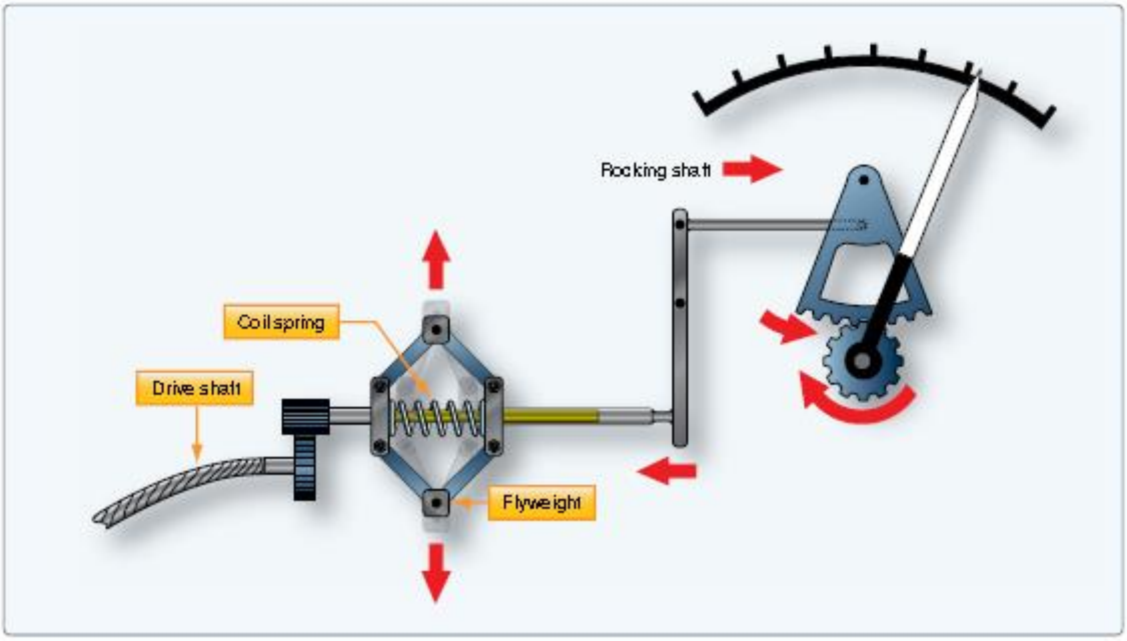


Figure 10-53. *The simplified mechanism of a flyweight type mechanical tachometer.*

Electric Tachometers

1. It is not practical to use a mechanical linkage between theengine and the rpm indicator on aircraft with engines notmounted in the fuselage just forward of the instrument panel.
2. Greater accuracy with lower maintenance is achieved throughthe use of electric tachometers.
3. A popular electric tachometer system makes use of a smallAC generator mounted to a reciprocating engine's gear caseor the accessory drive section of a turbine engine.
4. As theengine turns, so does the generator. The frequency outputof the generator is directly proportional to the speed of theengine.
5. It is connected via wires to a synchronous motor inthe indicator that mirrors this output.

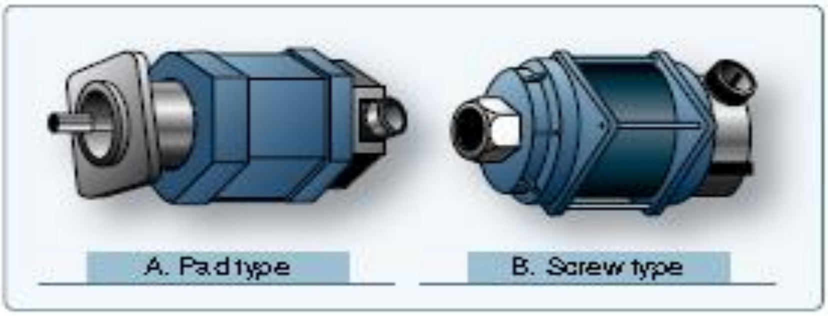
A. The dual tachometer

1. Consists of two tachometer indicator units housed in a single case.

2. The indicator pointers showsimultaneously, on one or two scales, the rpm of two engines.
3. A dual tachometer on a helicopter often shows the rpm ofthe engine and the rpm of the main rotor.
4. A comparison ofthe voltages produced by the two tach generators of this typeof helicopter indicator gives information concerning clutchslippage.
5. A third indication showing this slippage is sometimesincluded in the helicopter tachometer. [*Figure 10-57]*

B. Tachometer Probes

1. **Some turbine engines use tachometer probes** for rpmindication, rather than a tach generator system.
2. They providea great advantage in that there are no moving parts.
3. They aresealed units that are mounted on a flange and project intothe compressor section of the engine.
4. A magnetic field is setup inside the probe that extends through pole pieces and outthe end of the probe.
5. A rotating gear wheel, which movesat the same speed as the engine compressor shaft, alters themagnetic field flux density as it moves past the pole pieces atclose proximity.
6. This generates voltage signals in coils insidethe probe.
7. The amplitude of the EMF signals vary directlywith the speed of the engine.



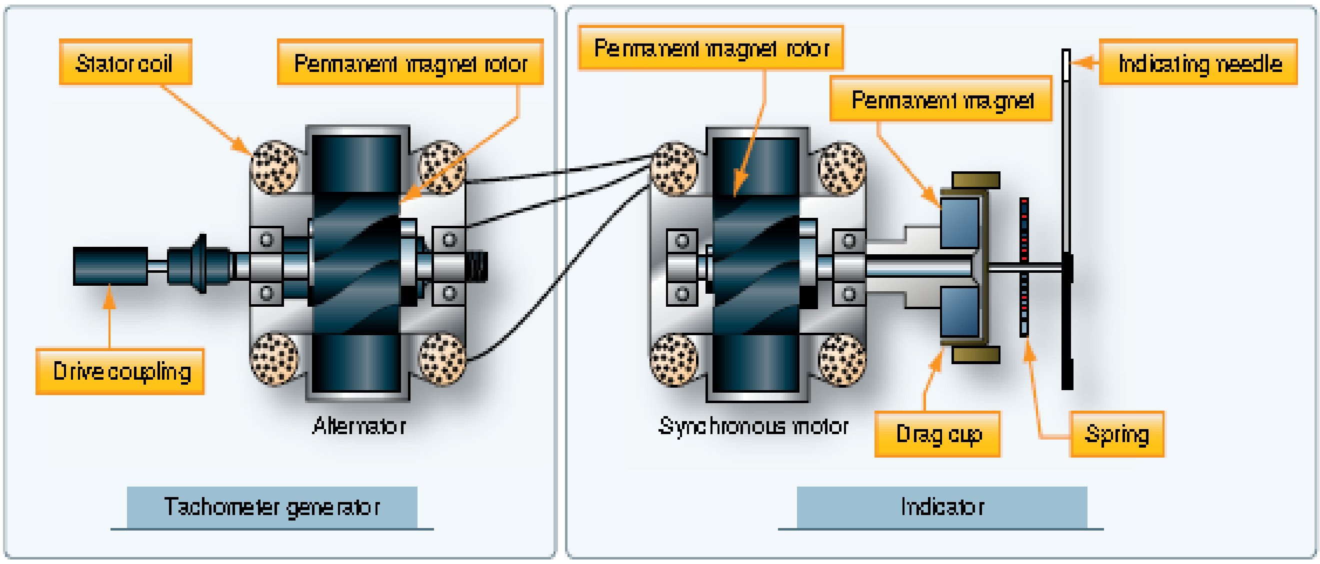


Figure 10-55. *An electric tachometer system with synchronous motors and a drag cup indicator.*

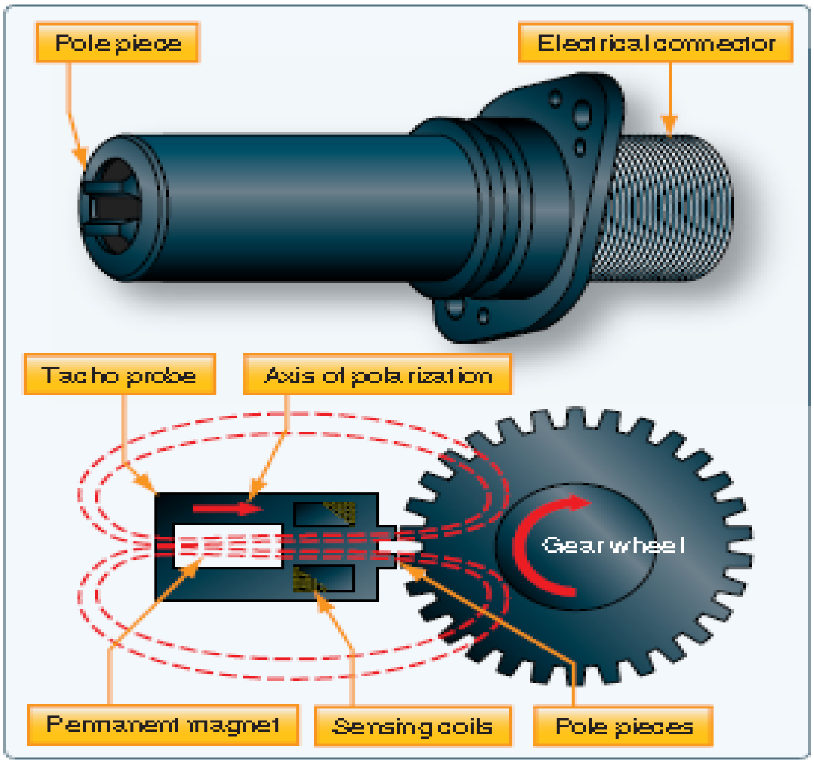


Figure 10-58. A tacho probe has no moving parts. The rate of magnetic flux field density change is directly related to engine speed.

Temperature Measuring Instruments

The temperature of numerous items must be known foran aircraft to be operated properly. Engine oil, carburetormixture, inlet air, free air, engine cylinder heads, heater ducts,and exhaust gas temperature of turbine engines are all itemsrequiring temperature monitoring.

Electrical Resistance Thermometer

Principle

For most metals, electrical resistance changes as the temperature of the metal changes. This is the principle upon which a resistance thermometer operates. Typically, the electrical resistance of a metal increases as the temperature rises.

1. The principle parts of the electrical resistance thermometerare the indicating instrument, the temperature-sensitiveelement (or bulb), and the connecting wires and plugconnectors.
2. Electrical resistance thermometers are usedwidely in many types of aircraft to measure carburetor air,oil, free air temperatures, and more.
3. They are used to measurelow and medium temperatures in the –70 °C to 150 °C range.
4. The metal resistor is subjectedto the fluid or area in which temperature needs to bemeasured.
5. It is connected by wires to a resistance measuringdevice inside the cockpit indicator.
6. The instrument dial iscalibrated in degrees Fahrenheit or Celsius as desired ratherthan in ohms.
7. As the temperature to be measured changes, theresistance of the metal changes and the resistance measuringindicator shows to what extent.
8. A typical electrical resistance thermometer looks like anyother temperature gauge.
9. Indicators are available in dualform for use in multiengine aircraft.
10. Most indicators areself-compensating for changes in cockpit temperature.
11. Theheat-sensitive resistor is manufactured so that it has a definiteresistance for each temperature value within its workingrange.
12. The temperature-sensitive resistor element is a lengthor winding made of a nickel/manganese wire or other suitablealloy in an insulating material.

13. The resistor is protected bya closed-end metal tube attached to a threaded plug with ahexagonal head.

Figure 10-68. *An electric resistance thermometer sensing bulb.*

Wheatstone-Bridge Meter

1. **It operates on the principle of balancing one unknown resistor against other known resistances**.
2. Three equal valuesof resistance *[Figure 10-69A, B,* and *C]* are connectedinto a diamond shaped bridge circuit.
3. A resistor with anunknown value *[Figure 10-69D]* is also part of the circuit.
4. The unknown resistance represents the resistance of thetemperature bulb of the electrical resistance thermometersystem.
5. A galvanometer is attached across the circuit atpoints X and Y.

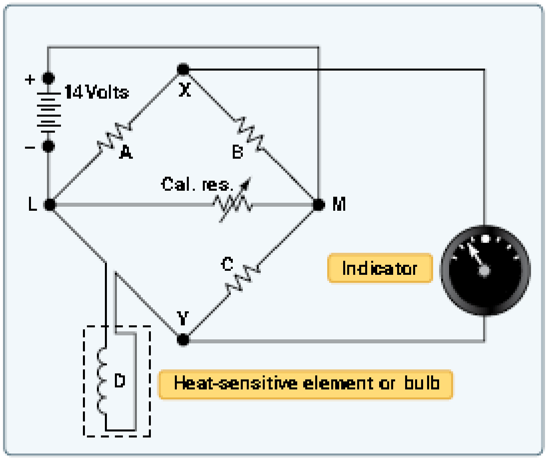


Figure 10-69. *The internal structure of an electric resistance thermometer indicator features a bridge circuit, galvanometer, and variable resistor, which is outside the indicator in the form of the temperature sensor.*

6. When the temperature causes the resistance of the bulb toequal that of the other resistances, no potential differenceexists between points X and Y in the circuit.
7. Therefore, nocurrent flows in the galvanometer leg of the circuit.
8. If thetemperature of the bulb changes, its resistance also changes,and the bridge becomes unbalanced, causing current to flowthrough the galvanometer in one direction or the other.
9. Thegalvanometer pointer is actually the temperature gaugepointer.
10. As it moves against the dial face calibrated in degrees,it indicates temperature.
11. Many indicators are provided witha zero adjustment screw on the face of the instrument.
12. Thisadjusts the zeroing spring tension of the pointer when thebridge is at the balance point (the position at which the bridgecircuit is balanced and no current flows through the meter).

Thermocouple Temperature Indicators

1. A thermocouple is a circuit or connection of two unlikemetals.
2. The metals are touching at two separate junctions.
3. If one of the junctions is heated to a higher temperature thanthe other, an electromotive force is produced in the circuit.
4. This voltage is directly proportional to the temperature.
5. A voltmeter is placed across the colderof the two junctions of the thermocouple.
6. It is calibrated in degrees Fahrenheit or Celsius, as needed.

7. The hotter the hightemperaturejunction (hot junction) becomes, the greater theelectromotive force produced, and the higher the temperatureindication on the meter. *[Figure 10-71]*

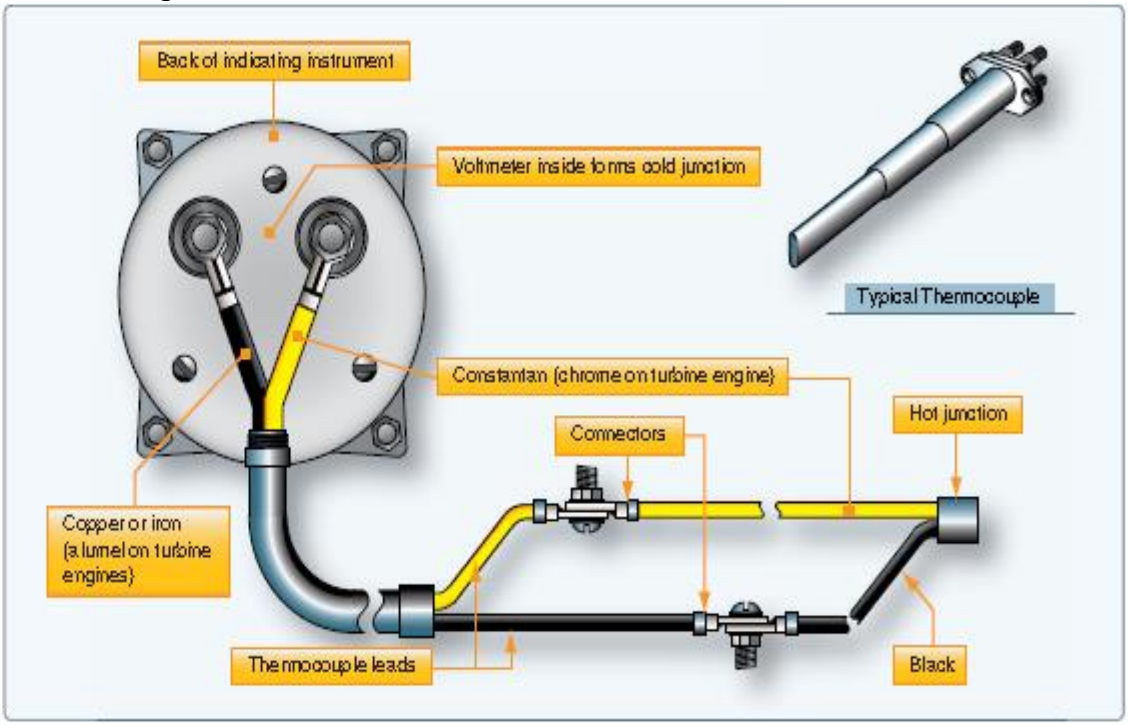


Figure 10-71. *Thermocouples combine two unlike metals that cause current flow when heated.*

8. Thermocouples are used to measure high temperatures.
9. Twocommon applications are the measurement of cylinder headtemperature (CHT) in reciprocating engines and exhaust gastemperature (EGT) in turbine engines.
10. Thermocouple leadsare made from a variety of metals, depending on the maximumtemperature to which they are exposed.
11. Iron and constantan,or copper and constantan, are common for CHT measurement.
12. Chromel and alumel are used for turbine EGT thermocouples.
13. The amount of voltage produced by the dissimilar metals whenheated is measured in millivolts.
14. Two common types are the gasket and thebayonet.
15. In the gasket type, two rings of the dissimilar metalsare pressed together to form a gasket that can be installedunder a spark plug or cylinder hold down nut.
16. In the bayonettype, the metals come together inside a perforated protectivesheath.
17. Bayonet thermocouples fit into a hole or well in acylinder head.

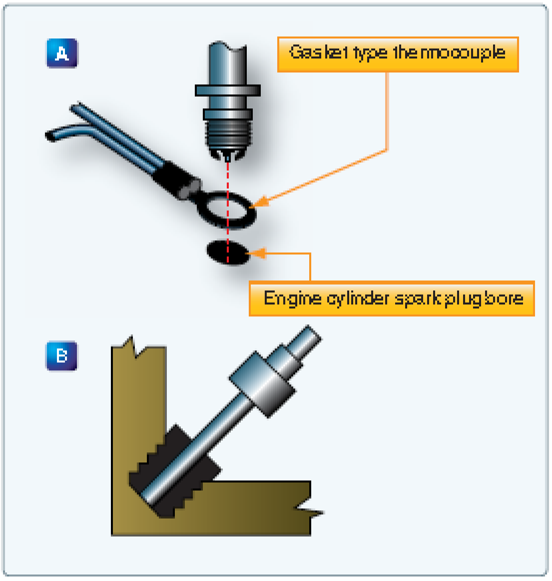


Figure 10-72. *A cylinder head temperature thermocouple with a gasket type hot junction is made to be installed under the spark plug or a cylinder hold down nut of the hottest cylinder (A). A bayonet type thermocouple is installed in a bore in the cylinder wall (B).*

18. The cold junction of the thermocouple circuit is inside theinstrument case.
19. Since the electromotive force set up in the circuit varies with the difference in temperature between the hot and cold junctions.
20. This is accomplished by using a bimetallic spring connected to the indicator mechanism.
21. When the leads are disconnected fromthe indicator, the temperature of the cockpit area aroundthe instrument panel can be read on the indicator dial.

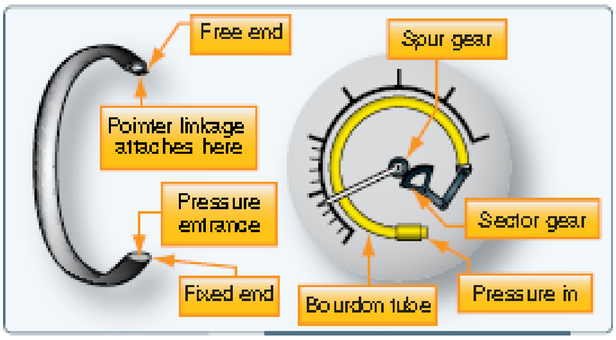
Figure 10-73. *Typical thermocouple temperature indicators.*

Pressure Measuring Instruments

1. Pressure-sensing instruments can be found in theflight group and the engine group.
2. They can be either directreading or remote sensing.
3. These are some of the most criticalinstruments on the aircraft and must accurately inform thepilot to maintain safe operations.

4. The three fundamental pressure-sensing mechanisms used in aircraft instrument systems are the Bourdon tube, the diaphragm or bellows, and the solid-state sensing device.

Bourdon Tube Pressure Gaugeis illustrated in *Figure 10-9.*



1. The open end of this coiled tube is fixed in place and the other end is sealedand free to move.
2. When a fluid that needs to be measured isdirected into the open end of the tube, the unfixed portionof the coiled tube tends to straighten out.
3. The higher thepressure of the fluid, the more the tube straightens. When thepressure is reduced, the tube recoils.
4. A pointer is attachedto this moving end of the tube, usually through a linkageof small shafts and gears.
5. By calibrating this motion of thestraightening tube, a face or dial of the instrument can becreated.
6. The Bourdon tube is the internal mechanism for manypressure gauges used on aircraft.
7. When high pressures need tobe measured, the tube is designed to be stiff.
8. Gauges used toindicate lower pressures use a more flexible tube that uncoilsand coils more readily.
9. Most Bourdon tubes are made frombrass, bronze, or copper.
10. Bourdon tube gauges are simple and reliable.
11. Some of theinstruments that use a Bourdon tube mechanism includethe engine oil pressure gauge, hydraulic pressure gauge,oxygen tank pressure gauge, and deice boot pressure gauge.
12. Bourdon tubemechanisms can also be used to measure temperature.

Diaphragm and Bellows Type Pressure Gauge

1. The diaphragm and bellows are employed in aircraft instruments for pressuremeasurement.
2. The diaphragm is a hollow, thin-walled metal disk, usually corrugated.
3. When pressure is introduced through an opening on one side of the disk, the entire disk expands.
4. By placing linkage in contact against the other side of the disk, the movement of the pressurized diaphragm can be transferred to a pointer
5. Pointer registers the movement against the scale on the instrument face. *[Figure 10-11]*

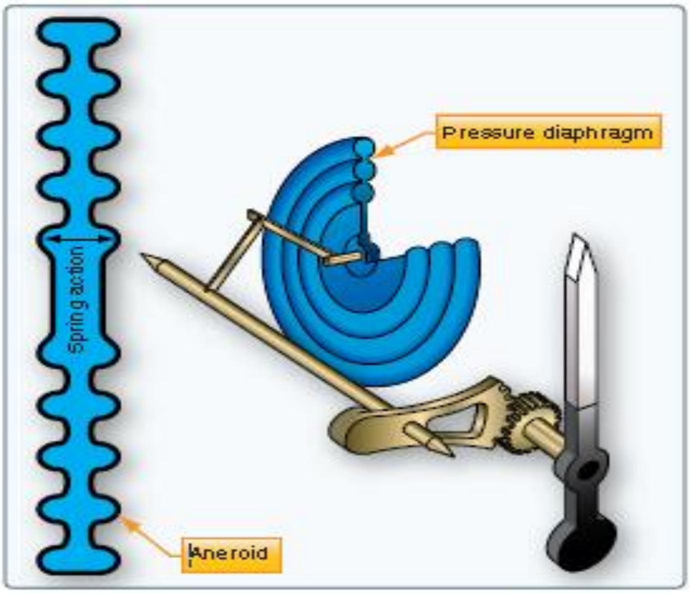


Figure 10-11. *A diaphragm used for measuring pressure. An evacuated sealed diaphragm is called an aneroid.*

Bellows Type Pressure Gauge

1. When a number of diaphragm chambers are connectedtogether, the device is called a bellows.
2. This accordion likeassembly of diaphragms can be very useful whenmeasuring the difference in pressure between two gases,called differential pressure.
3. Just as with a single diaphragm,it is the movement of the side walls of the bellows assemblythat correlates with changes in pressure and to which apointer linkage and gearing is attached to inform the pilot.