UNIT - V

AIRCRAFT INSTRUMENTS

INTRODUCTION

- Enable an airplane to be operated with maximum performance and enhanced safety
- Manufacturers provide the necessary flight instruments
- Pilots need to understand how they operate

Types

- Flight Instruments
  - Altimeter, Airspeed Indicator, Mach meter, Vertical Speed Indicator, Attitude Indicator (Artificial Horizon), Turn and Bank Indicator , Heading Indicator
- Navigation Instruments
  - Accelerometer, Horizontal Situation Indicator
- Engine Instruments
  - Electrical Tachometer, Oil Pressure Indicator, Exhaust Gas Temperature,
- Pressure Gauges
  - Bourdon Tube , Diaphragm Type ,Hydraulic

Flight Instruments

- They provide the pilot with information about the flight situation of that aircraft, such as altitude, speed and direction.

- Used in conditions of poor visibility, such as in clouds, when such information is not available from visual reference outside the aircraft.

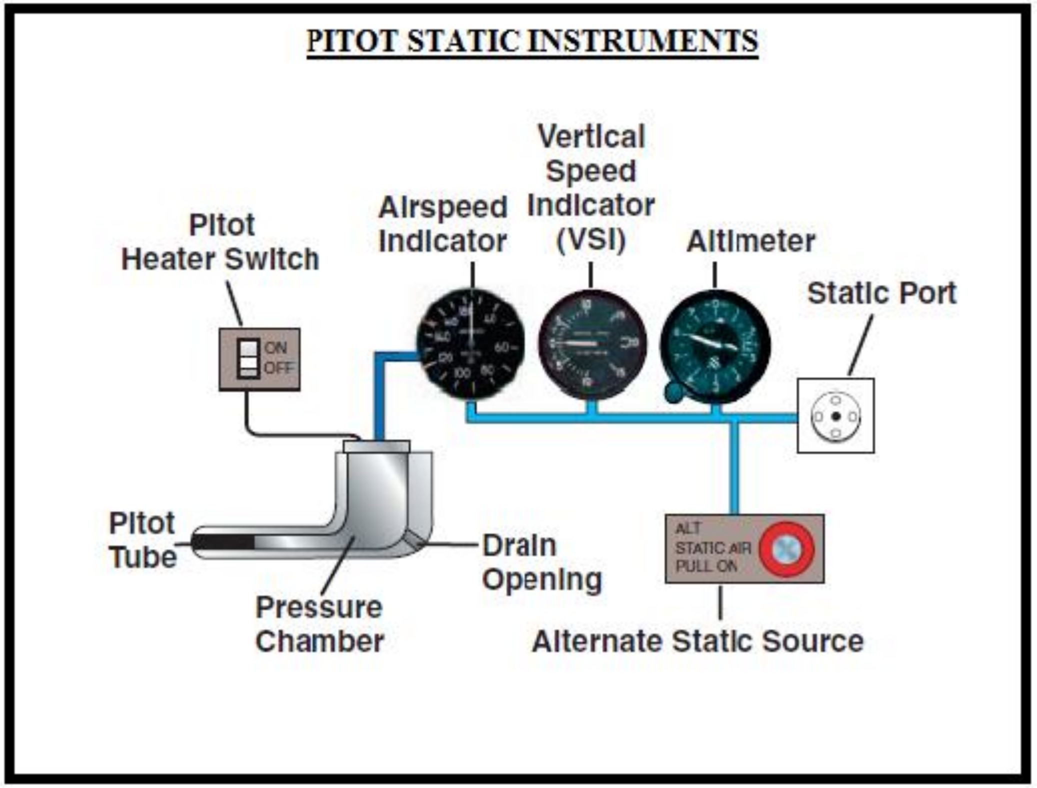
Flight Instruments

Airspeed Indicator, Attitude Indicator, Altimeter,

Turn and Bank Indicator, Heading Indicator, Vertical Speed Indicator

Pitot-Static Flight Instruments

- Two Major Parts:
  - Impact Pressure Chamber and Lines
  - Static Pressure Chamber and Lines



Blockage of Pitot-Static System

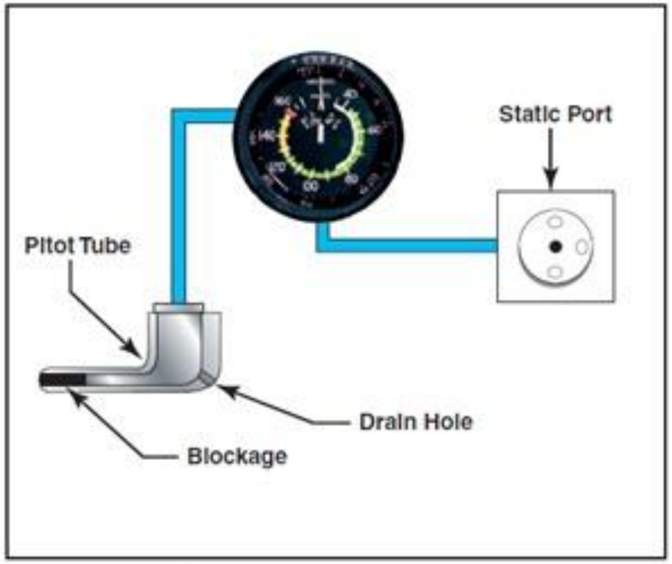


Figure A blocked pitot tube, but clear drain hole.

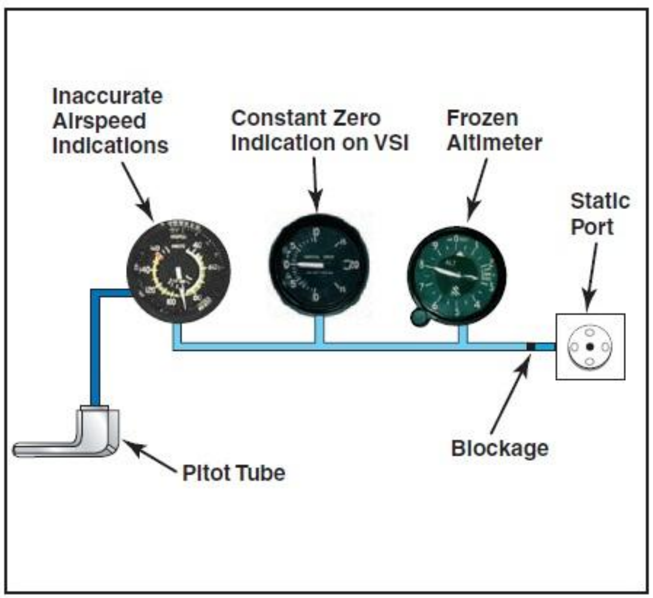


Figure Blocked static system.

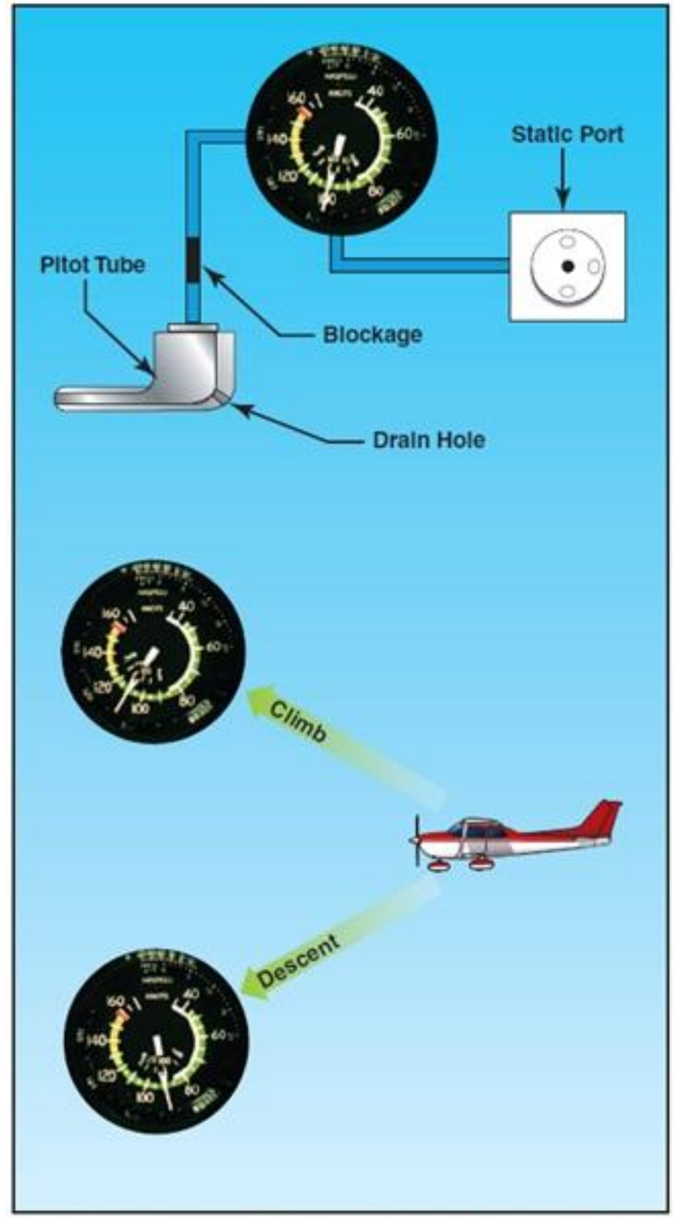
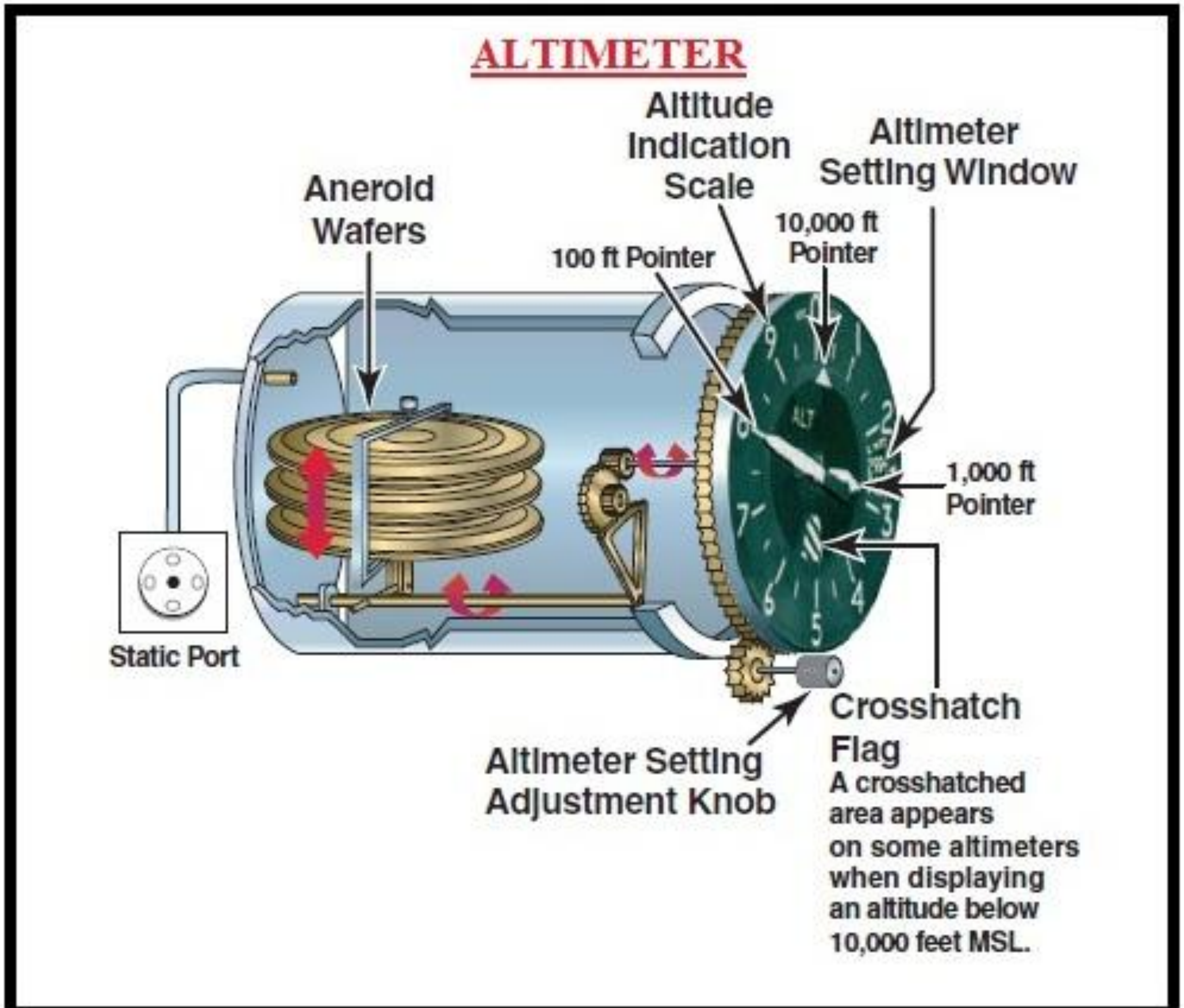
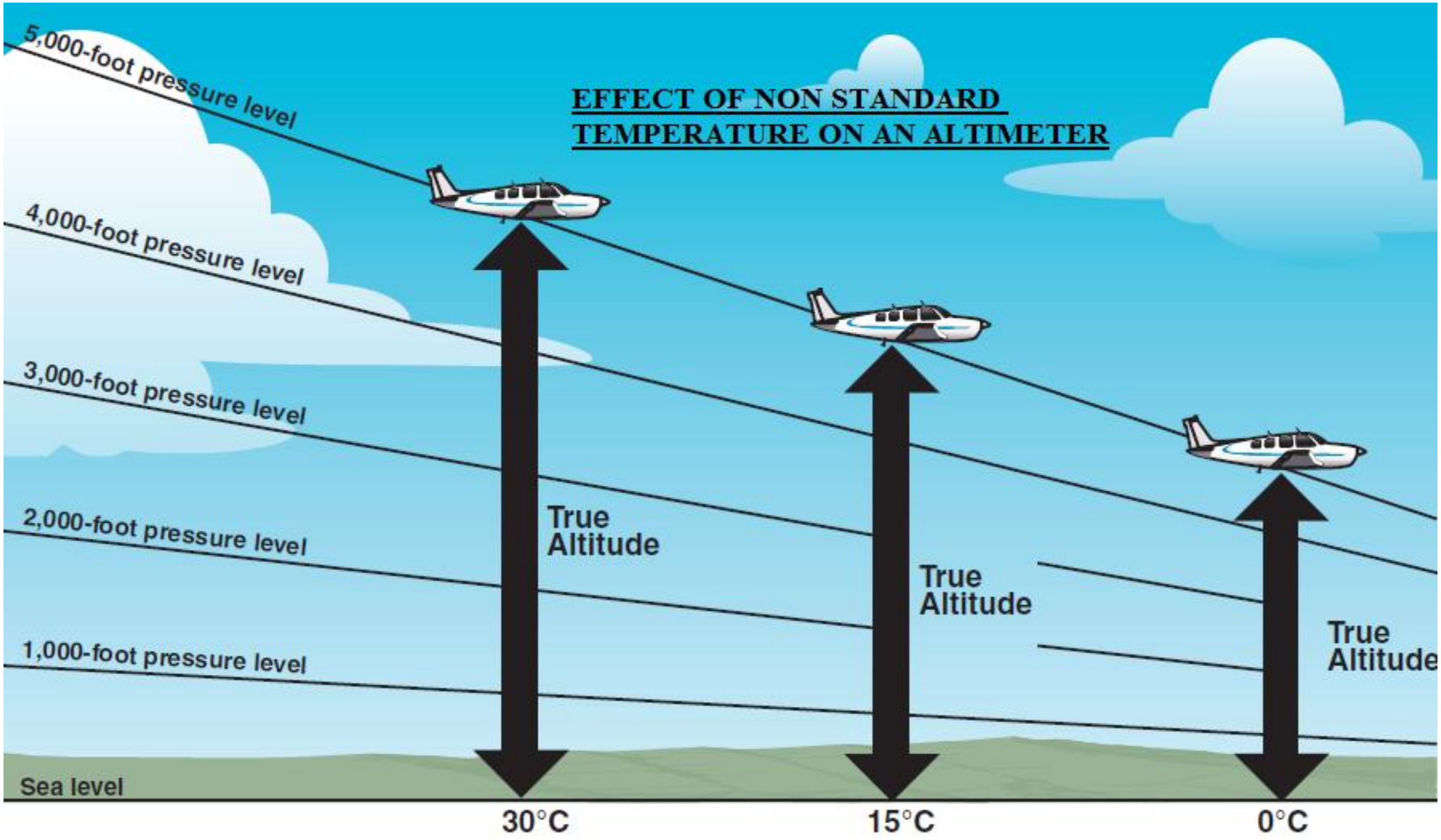


Figure Blocked pitot system with clear static system.

ALTIMETER


ALTIMETER
Altitude Indication Scale
Altimeter Setting Window
Aneroid Wafers
10,000 ft Pointer
100 ft Pointer
1,000 ft Pointer
Static Port
Crosshatch Flag
A crosshatched area appears on some altimeters when displaying an altitude below 10,000 feet MSL.
Altimeter Setting Adjustment Knob

Effect of Temperature on an Altimeter



Types of Altitude

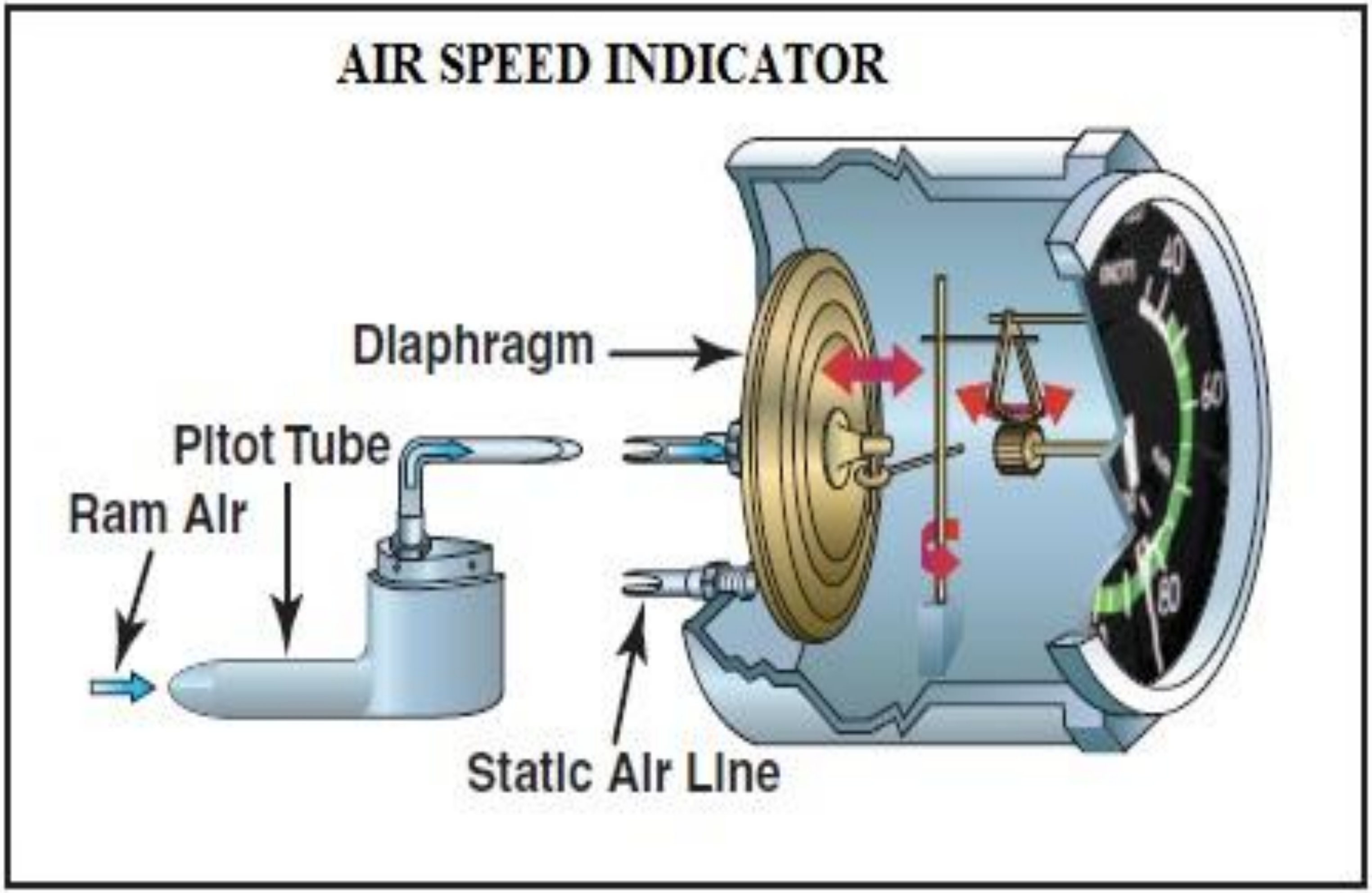
- **Indicated Altitude** : Altitude read directly from the altimeter (uncorrected)
- **True Altitude** : The vertical distance of the airplane above sea level—the actual altitude. It is often expressed as feet above mean sea level (MSL). Airport, terrain, and obstacle elevations on aeronautical charts are true altitudes.
- **Absolute Altitude** : The vertical distance of an airplane above the terrain, or above ground level (AGL).

Types of Altitude

- **Pressure Altitude :** The altitude indicated when the altimeter setting window (barometric scale) is adjusted to 29.92 in. Hg (Corrected to 15°C). Pressure altitude is used to compute density altitude, true altitude, true airspeed, and other performance data.

- **Density Altitude :** Pressure altitude corrected for variations from standard temperature. When conditions are standard, pressure altitude and density altitude are the same. If the temperature is above standard, the density altitude is higher than pressure altitude. If the temperature is below standard, the density altitude is lower than pressure altitude. This is an important altitude because it is directly related to the airplane's performance.

AIRSPEED INDICATOR (ASI)



Types of Airspeeds

- **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.

- **True Airspeed (TAS)** : Calibrated airspeed corrected for altitude and nonstandard temperature.

- **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.

ASI – Colour Codes

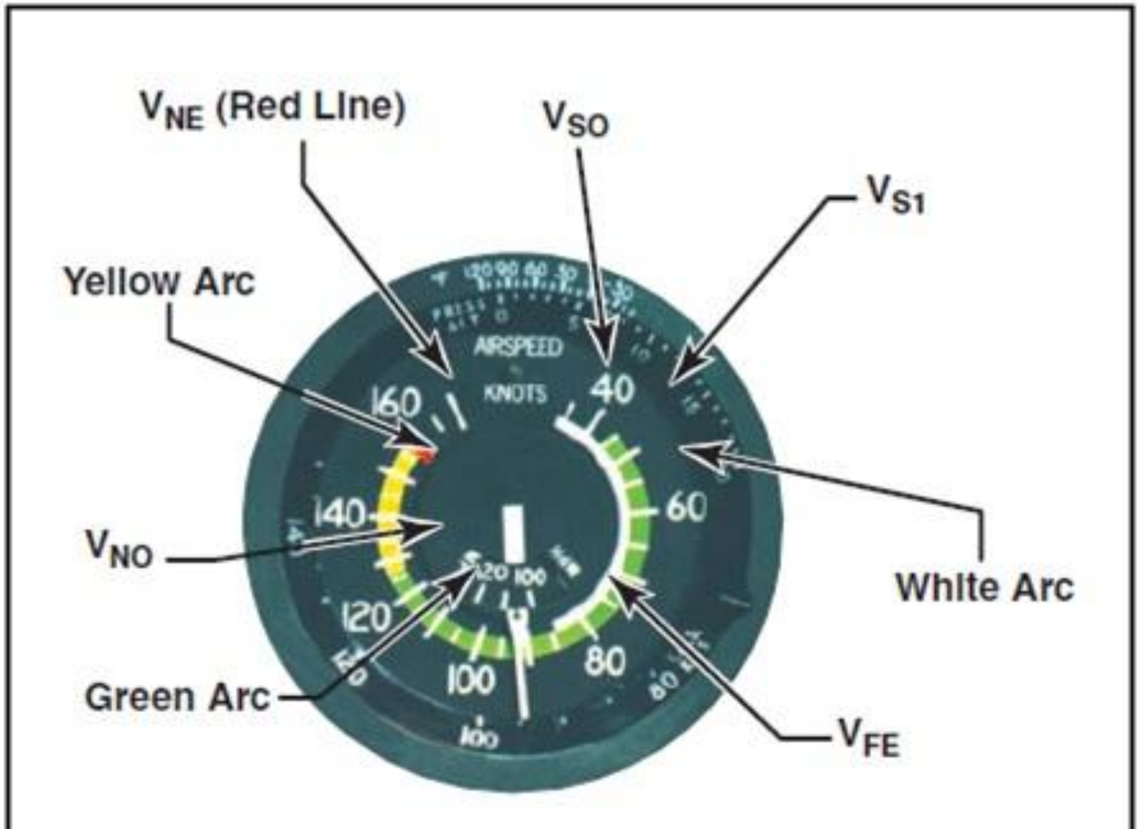


Figure . In addition to delineating various speed ranges, the boundaries of the color-coded arcs also identify airspeed limitations.

ASI – Colour Codes

- White arc—This arc is commonly referred to as the flap operating range since its lower limit represents the full flap stall speed and its upper limit provides the maximum flap speed. Approaches and landings are usually flown at speeds within the white arc.
- Lower limit of white arc (VS0)— The stalling speed or the minimum steady flight speed in the landing configuration. In small airplanes, this is the power-off stall speed at the maximum landing weight in the landing configuration (gear and flaps down).
- Upper limit of the white arc (VFE)—The maximum speed with the flaps extended.
- Green arc—This is the normal operating range of the airplane. Most flying occurs within this range.

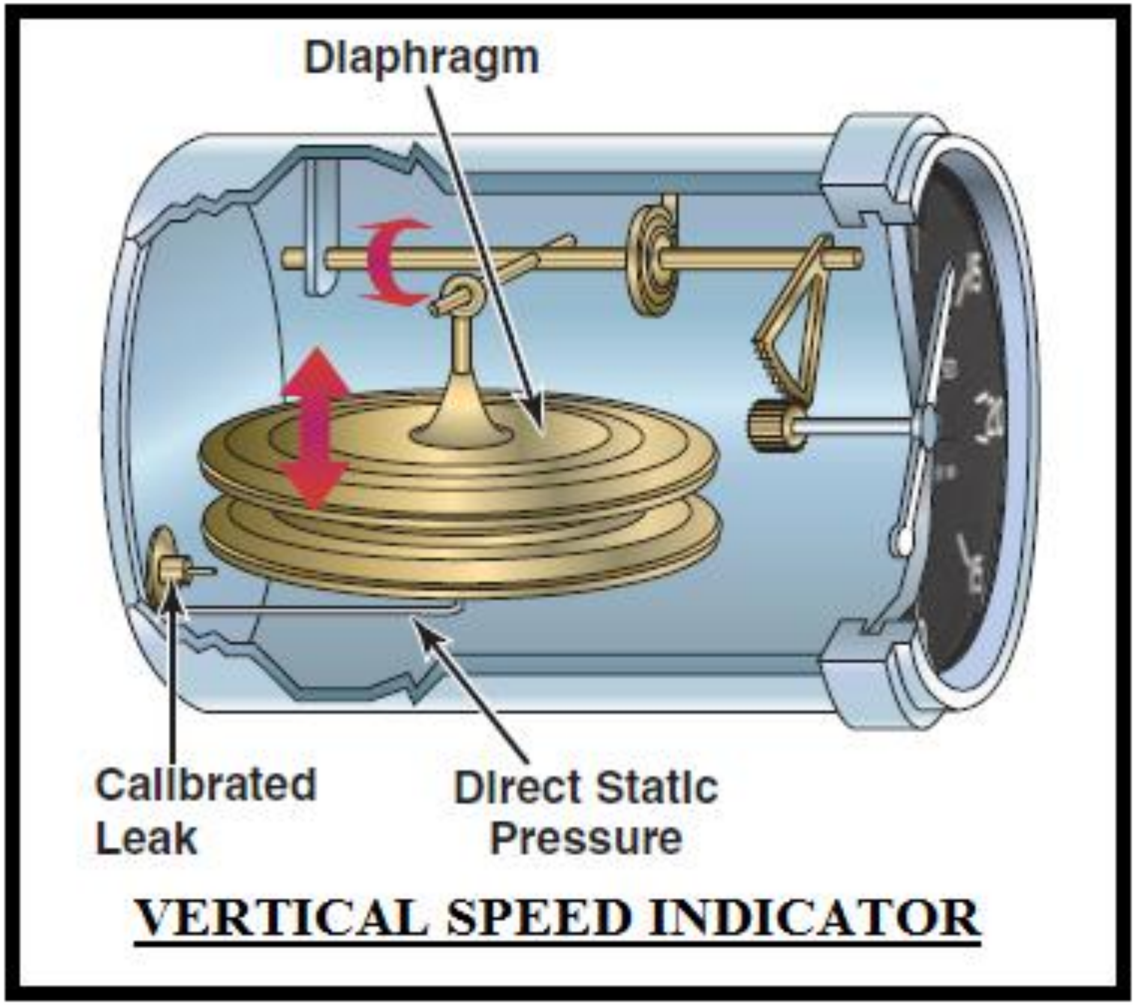
ASI – Colour Codes

- Lower limit of green arc (VS1)—The stalling speed or the minimum steady flight speed obtained in a specified configuration. For most airplanes, this is the power-off stall speed at the maximum takeoff weight in the clean configuration (gear up, if retractable, and flaps up).
- Upper limit of green arc (VNO)—The maximum structural cruising speed. Do not exceed this speed except in smooth air.
- Yellow arc—Caution range. Fly within this range only in smooth air, and then, only with caution

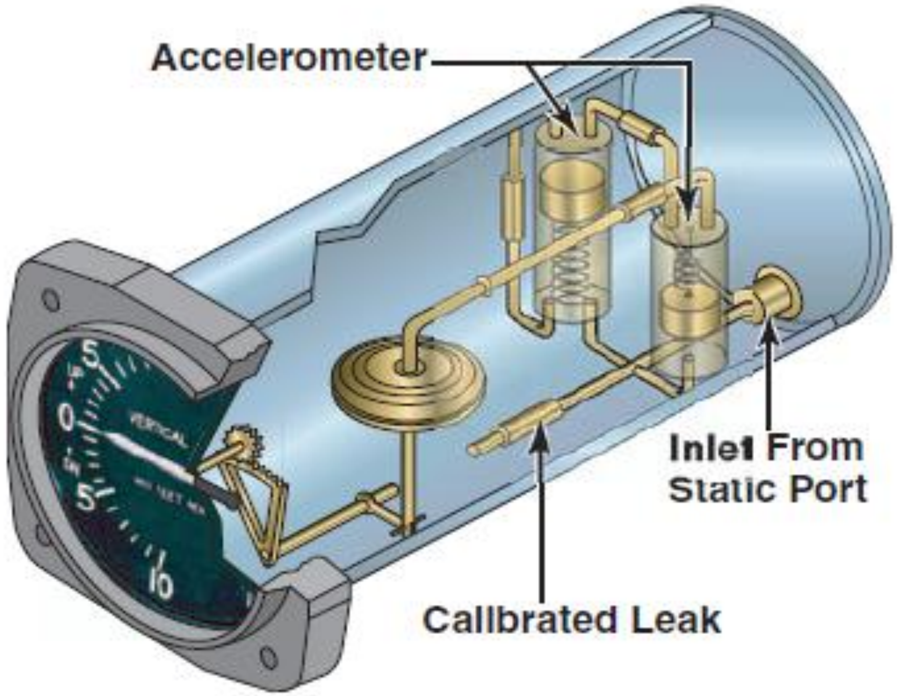
.

- Red line (VNE)—Never-exceed speed. Operating above this speed is prohibited since it may result in damage or structural failure.

VERTICAL SPEED INDICATOR (VSI)



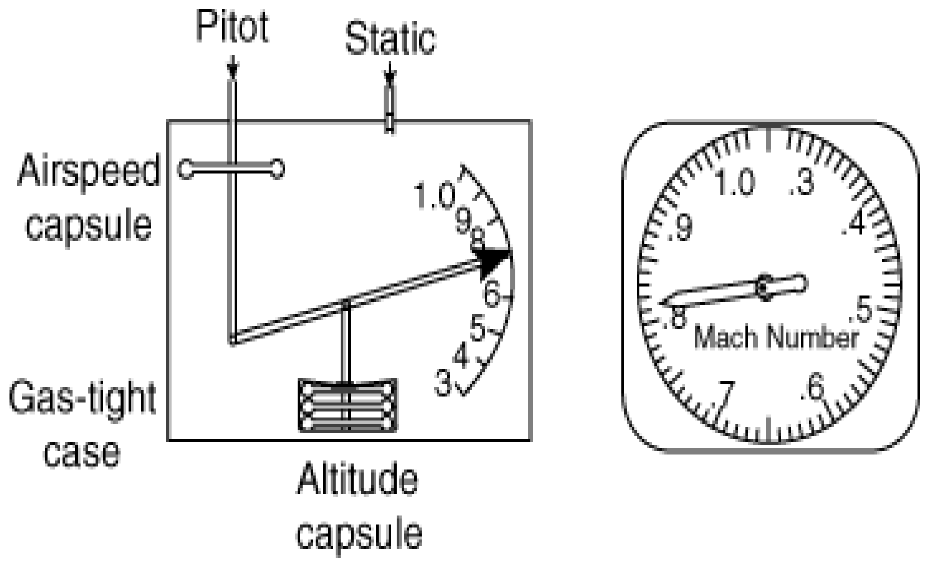
IVSI



An instantaneous vertical speed indicator incorporates accelerometers to help the instrument immediately indicate changes in vertical speed.

Machmeter

- The older mechanical Machmeters use an altitude aneroid and an airspeed capsule which together convert pitot-static pressure into Mach number. Modern electronic Machmeters use information from an air data computer system.

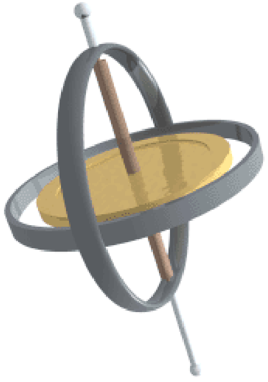


Gyroscopic Instruments

- Gyroscope : Device consisting of a wheel having much of its mass concentrated around the rim, mounted on a spinning axis.

Characteristics :

- Rigidity in Space : Directional reference
- Precession : Tendency of the gyro to react to an applied force 90^0 in the direction of rotation from the point the force is applied.



Principle

- **Rigidity in Space**

- Principle that a gyroscope remains in a fixed position in the plane in which it is spinning
- By mounting this wheel, or gyroscope, on a set of Gimbal rings, the gyro is able to rotate freely in any direction.
  - If the gimbal rings are tilted, twisted, or otherwise moved, the gyro remains in the plane in which it was originally.
  - Think of the gyro as being aligned with the horizon, and the airplane rotates around it.
- Stability increases if the rotor has great mass and speed
  - Approximately 15,000 rpm for the attitude indicator and 10,000 rpm for the heading indicator

Principle

- **Gyroscopic Precession**

  Whenever a force attempts to tilt the plane of rotation, the force is applied 90 degrees ahead of, and in the direction of rotation

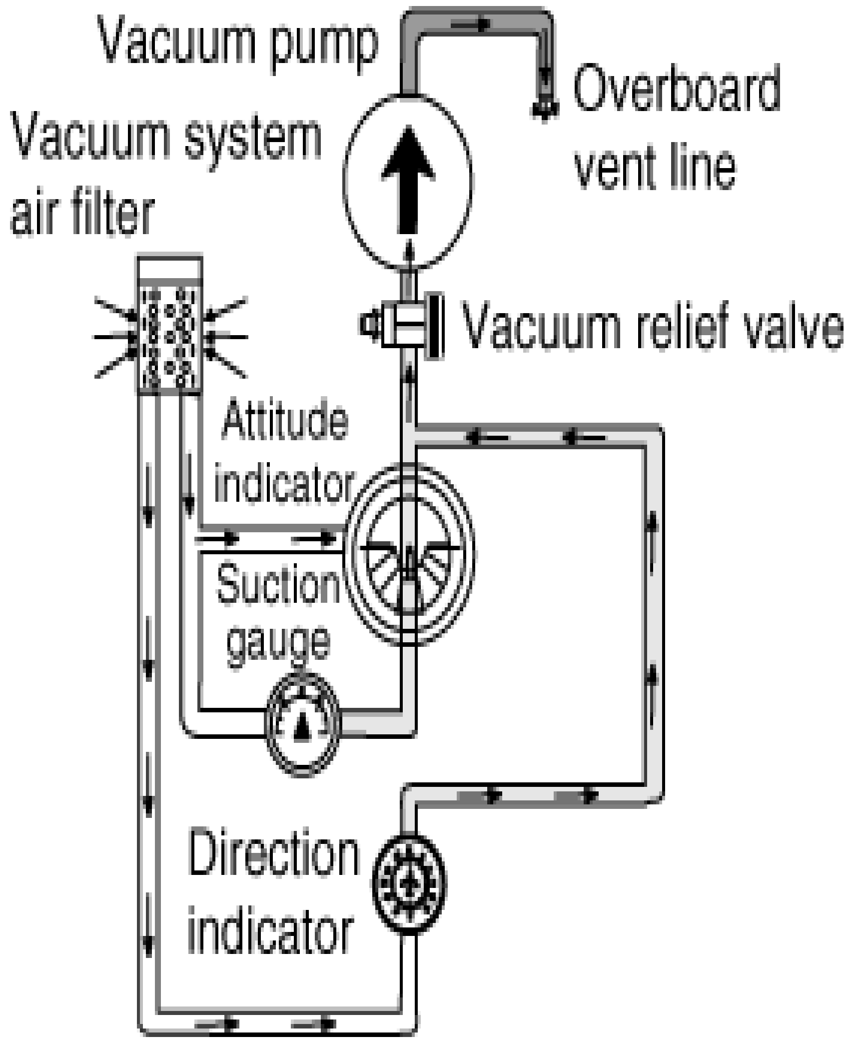
  - Inversely proportional to the speed of the rotor and proportional to the deflective force

Figure 17–44 Gyroscopic Precession

Power Sources

- **Vacuum System:**

  Runs the Attitude Indicator and Heading Indicator
  - Engine Driven Pump creates suction through system
  - Air sucked through system is diverted over "buckets" in gyroscope walls to turn gyros
  - Semi-frictionless design

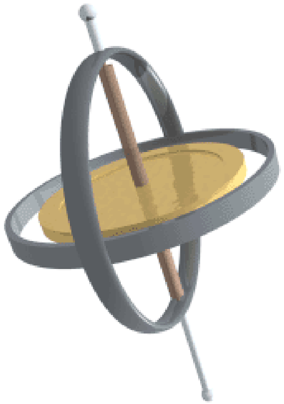


Power Sources

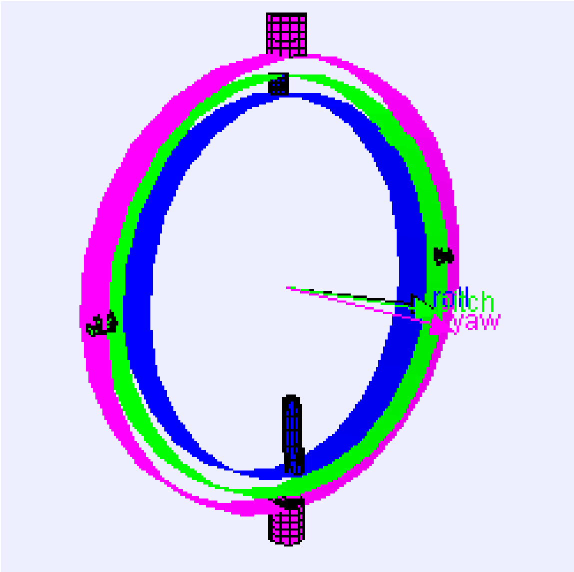
- **Electrical System:**

  The turn coordinator uses an electrical gyro so that in the event of a vacuum system failure, the pilot still has one working gyroscopic instrument

Gyroscopic Instruments



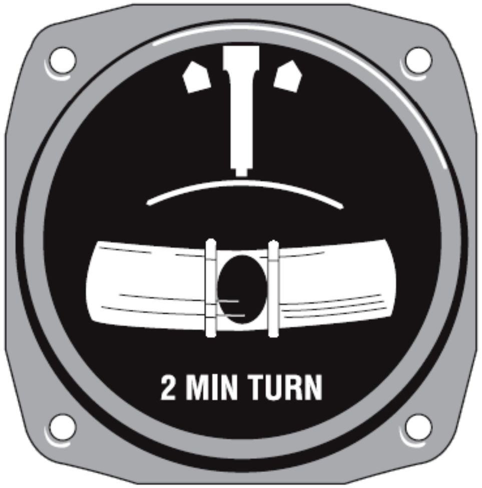
- Turn and Bank Indicator (or) Turn Coordinator
- Attitude Indicator (or)Artificial Horizon
- Heading Indicator

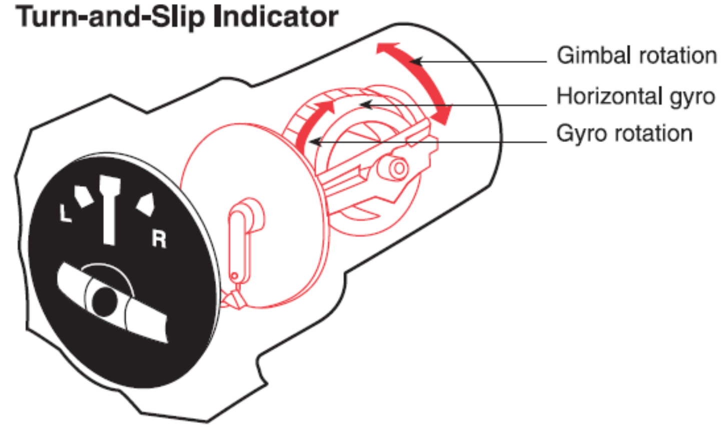


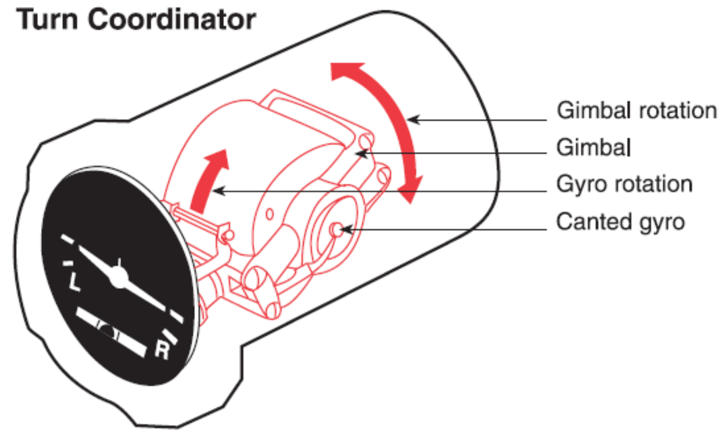
Turn and Bank Indicator

- Uses an electric gyroscope to give pilot information about rate of turn and rate of roll
  - Tells us direction and how quickly we are rolling initially
  - Then tells us rate of turn, or how many degrees per second
- Markings at "Standard Rate Turn", which the airplane will turn 360 degrees in 2 minutes
- Gyroscope mounted diagonally, balanced by a spring, and works by precession to sense bank angle
- Inclinometer (ball)
  - Separate instrument used to measure quality of turn
  - Ball on the inside of turn indicates a slipping turn
  - Ball on the outside of turn indicates a skidding turn

Turn and Bank Indicator







Inclinometer

Inclinometer (ball)

Separate instrument used to measure quality of turn

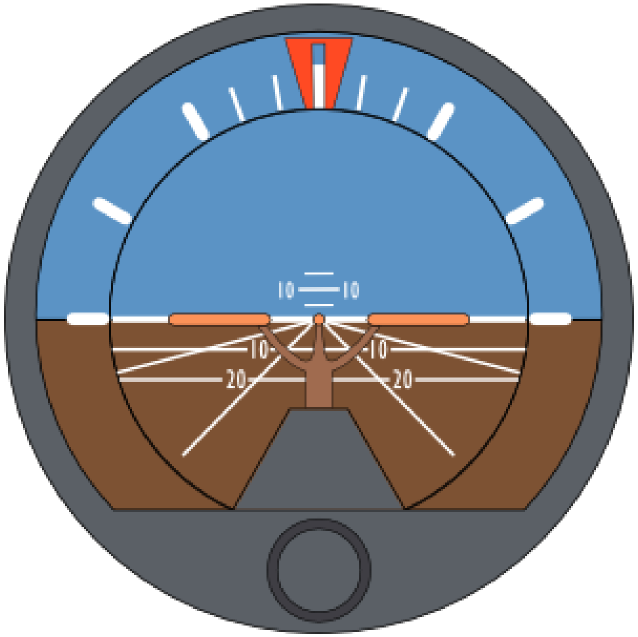
Ball on the inside of turn indicates a slipping turn

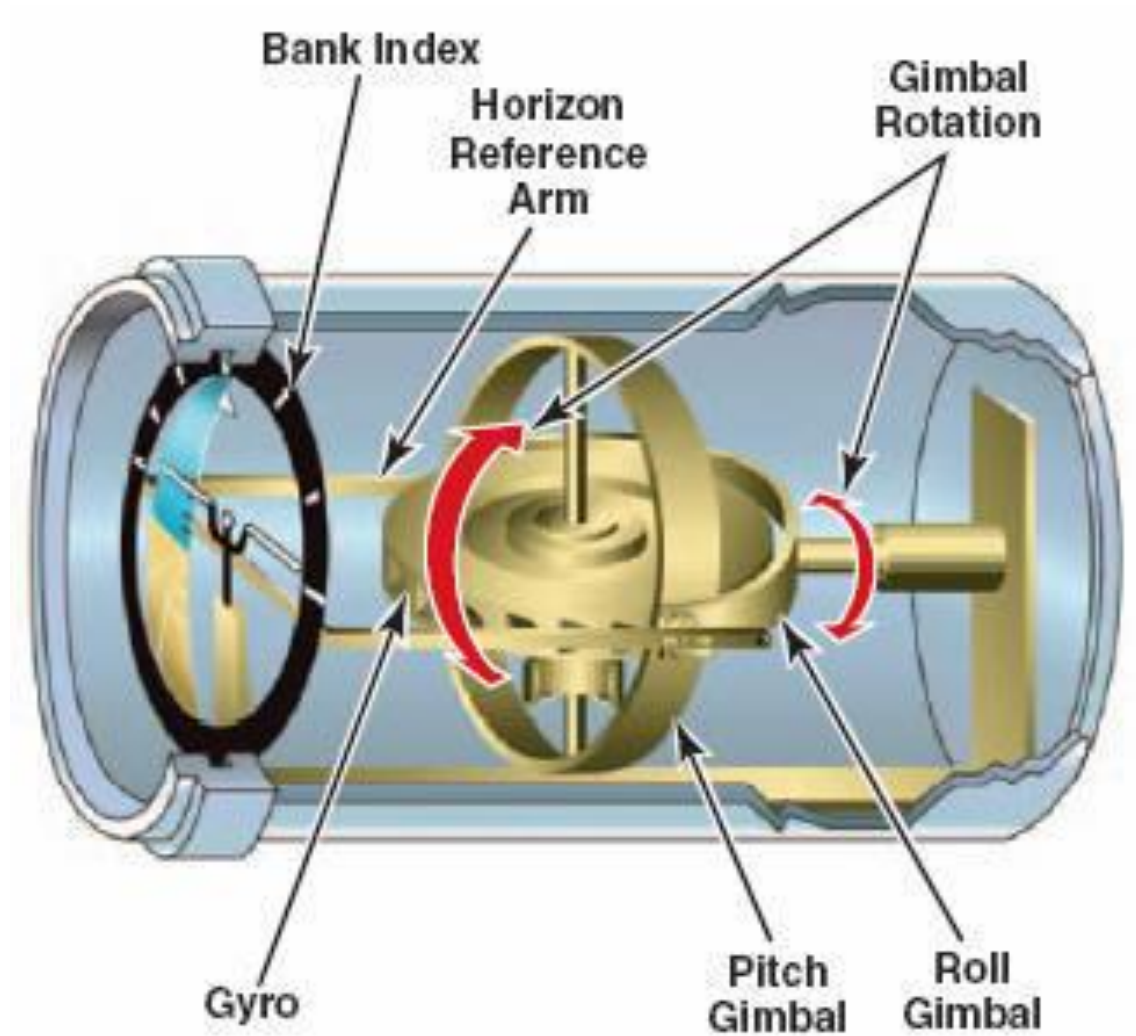
Ball on the outside of turn indicates a skidding turn

Attitude Indicator (or) Artificial Horizon

- Provides an artificial horizon to the pilot to display information about both pitch and bank
- Gyroscope has two gimbals that the aircraft can rotate about for pitch and bank
- 10,20,30,60,90 degree markings for bank
- Pitch angle is indicated by a series of lines, each representing 5° or 10° of pitch
- Pilot can set where the miniature airplane meets the horizon before takeoff

Attitude Indicator





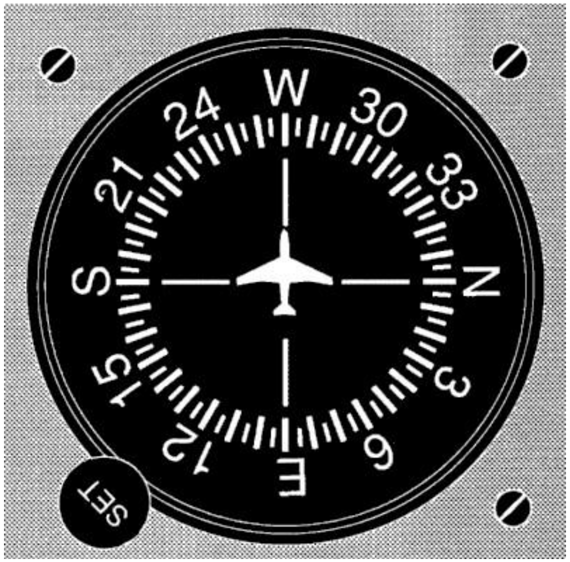
Heading Indicator

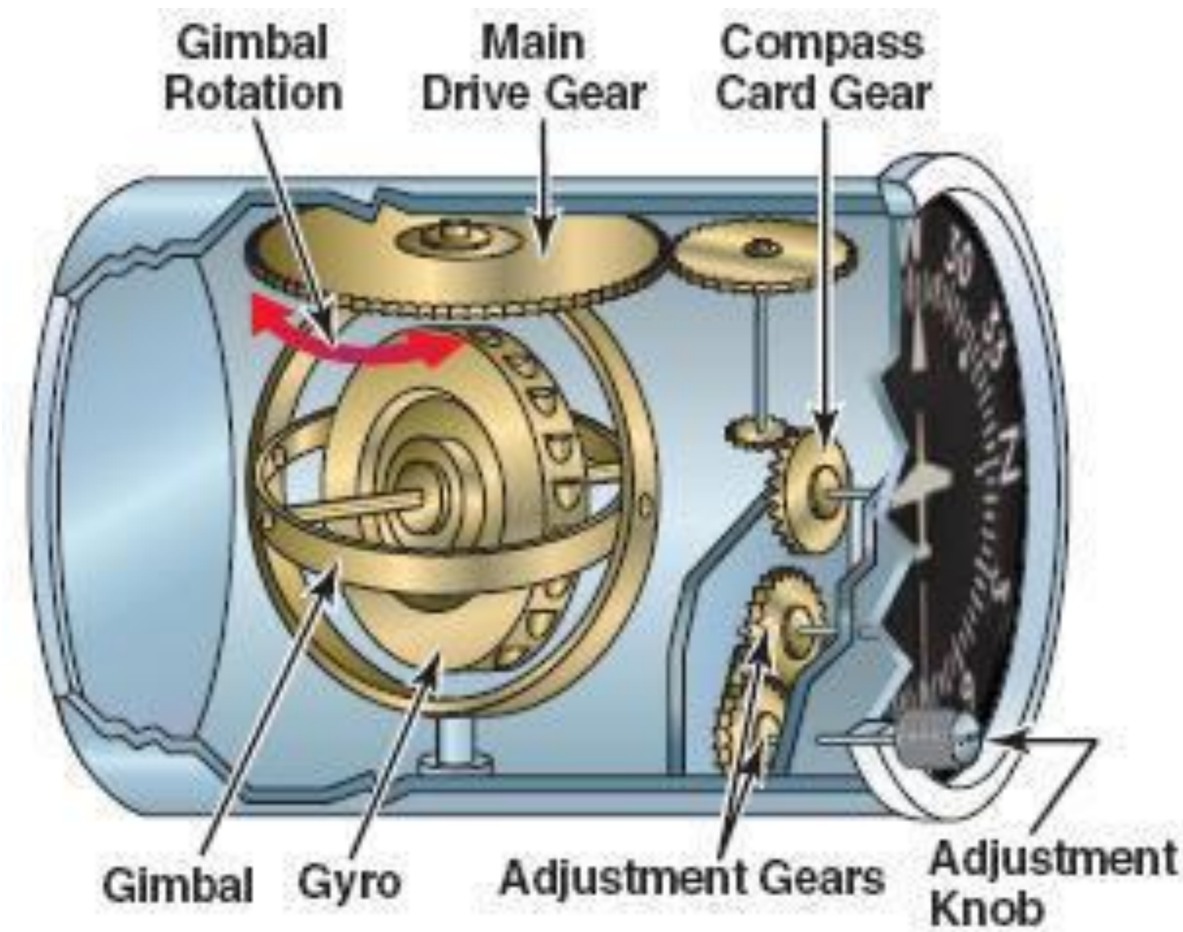
- There are a number of errors when using the magnetic compass. The gyroscopic heading indicator makes it easy to turn to headings.
- Unfortunately, the heading indicator does not seek magnetic north by itself
- Vertically mounted gyroscope with one gimbal gives us heading information
  - We set where the gyroscope considers north with the knob and it tells us heading as we rotate around it.

]**Errors**

- Drift
  - Because the earth rotates and because of small accumulated errors caused by friction and imperfect balancing of the gyro, the Heading Indicator will drift over time
  - Must be set every 15 min

Heading Indicator





NAVIGATION INSTRUMENTS

Accelerometer

- It is used on new airplanes during test flights to measure the acceleration loads on the aircraft structure.
- Serves as the basis for stress analysis as it gives an accurate indication of stresses imposed on airplane during flight.
- It measures accelerations exerted on airplane in gravity units.
- It indicates change only along the aircraft vertical axis
- It is graduated in gravity units from -5g to +12g.
- Vertical acceleration can be illustrated by carrying a heavy parcel in elevator

Accelerometer

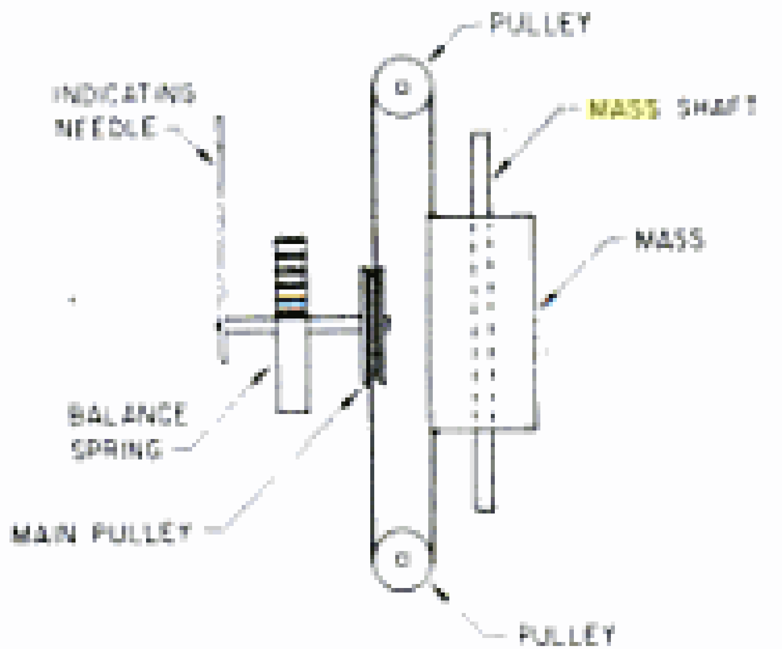


FIGURE 17–26 Diagram illustrating the principle of an accelerometer.

Horizontal Situation Indicator (HSI)

- It combines the information supplied by heading indicator with radio navigation information(VOR/ILS)
- It reduces eye motion of pilot
- Electrically or Pneumatically driven gyro for heading indicator
- Information from navigation radio is displayed through a deviation bar and selected course pointer
- When gyro is operating properly, the flag (NAV, HDG, GS) is retracted out of sight

HSI


NAV warning lag
Lubber line
Compass warning flag
Course select pointer
Heading select bug
TO/FROM indicator
Dual glideslope pointers
Glideslope deviation scale
Symbolic aircraft
Course deviation bar (CDI)
Heading select knob
Course select knob
Course deviation scale
Compass card
NAV
HDG
GS
GS
S
15
12
E
6
3
N
33
30
W
24

ENGINE INSTRUMENTS

Electrical Tachometer System

- They are used on large aircraft – distance from engine to instrument panel makes Mechanical tachometer impractical
- 3 phase AC alternator to generate signal
- The signal drives a synchronous motor inside the instrument – the motor synchronizes its speed with alternator
- The motor turns the drag cup
- Drag cup positions the needle on the face of the instrument

Electrical Tachometer System

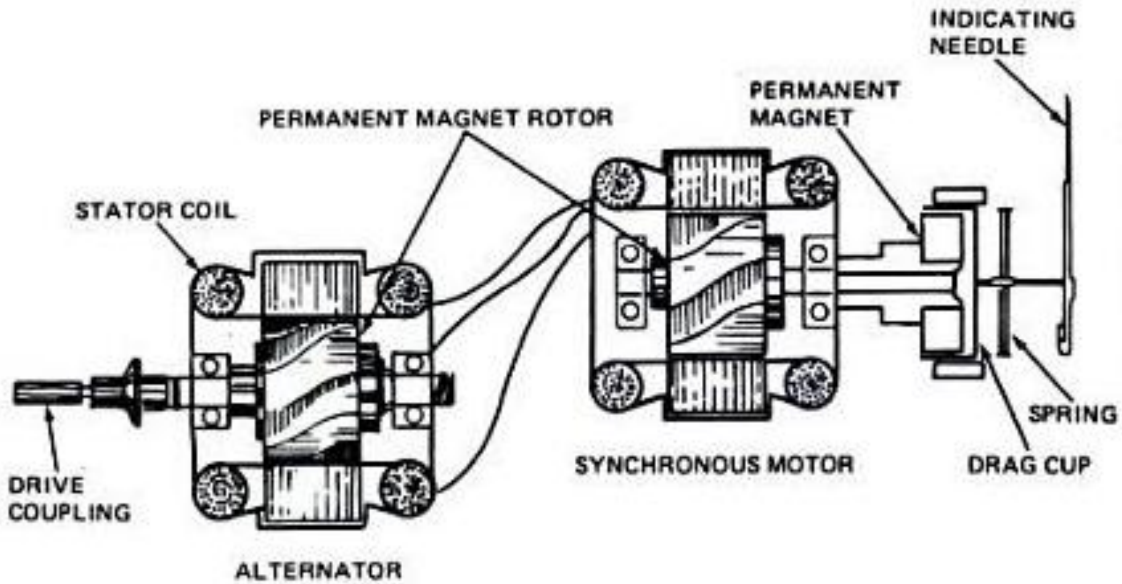


FIGURE 17–61 Electric tachometer system. (AC.)

Exhaust Gas Temperature Indicator (EGT)

- It is a primary instrument for monitoring turbine engine operation
- They are used to monitor the performance of the engines and make flight and maintenance adjustments.
- The system operate by placing thermocouples in the stream of exhaust gases exiting the engine.
- The thermocouple generate the current, which drives the indicator.
- The amount of current is very low and is amplified or adjusted in order to drive the indicator display.

Exhaust Gas Temperature Indicator (EGT)

- If Multiple probes are used, a selector switch on the instrument is used to allow selection of the cylinder being monitored.
- In turbine engine, system uses several probes in parallel.
- The average reading of the temperature and the indication does not change substantially if one probe should fail.

Exhaust Gas Temperature Indicator (EGT)

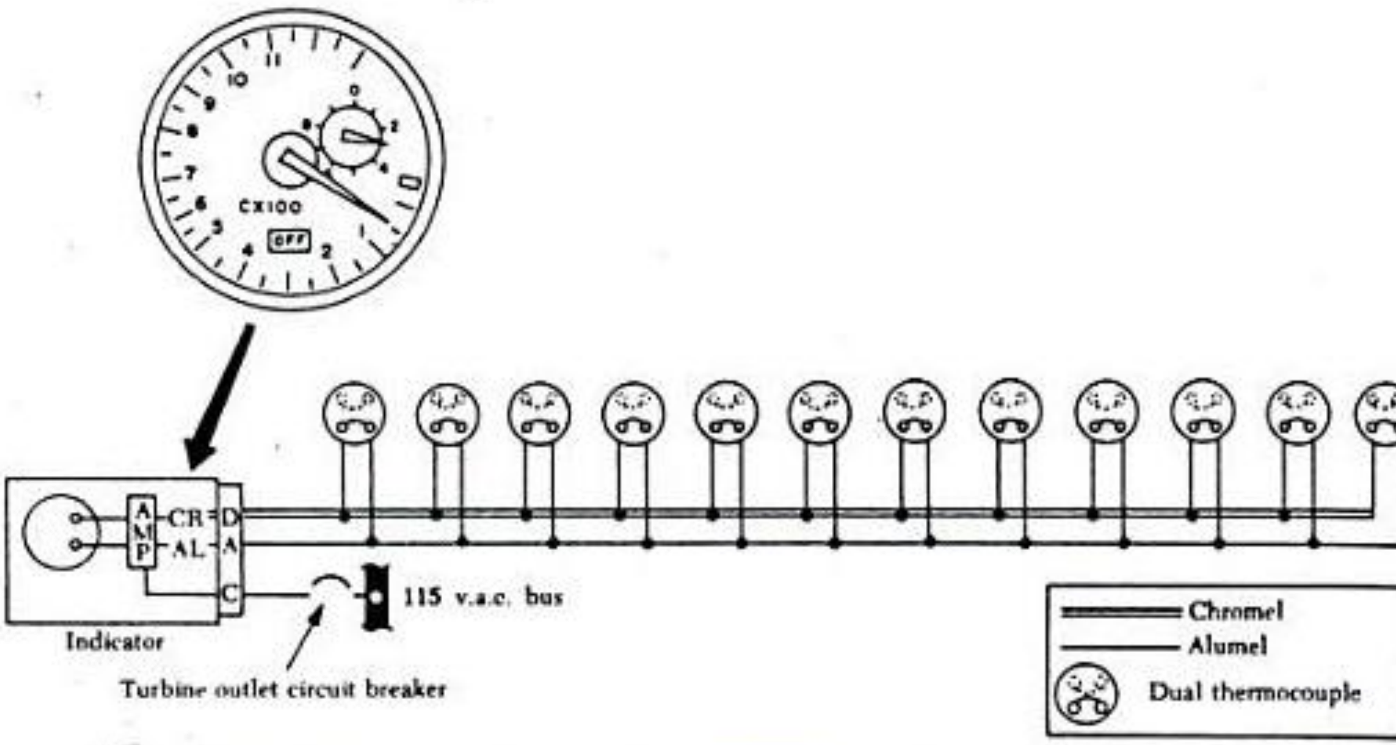


FIGURE 17–62 Simplified schematic drawing of a turbine-engine exhaust gas system.

Oil Pressure Indicator

- It can be mechanically operated or electrically powered.
- A Mechanically operated gauge uses an oil-pressure line from the engine to the instrument to operate a bourdon tube and gear segment to position the indicator needle.
- Restrictor in oil line prevent rapid oil loss if line breaks.
- Light oil is used in line between gauge and engine for quick response.

Oil Pressure Indicator

- Electric oil pressure sensors use pressure sensor on the engine, it varies its resistance as pressure changes.
- The pressure signal generated is processed and indicated in the cockpit display.

PRESSURE GAUGES

Bourdon – Tube Pressure Gauge

- The bourdon tube is made of spring tempered brass, bronze or beryllium copper.
- They have strong spring effect that cause the bourdon tube to return to its original position when pressure is released.
- When pressure enters the bourdon tube, the tube tends to straighten out
- This move the mechanical linkage connected to the sector gear
- The movement of sector gear causes spur gear to rotate and in turn moves the indicating needle along the scale.

Bourdon – Tube Pressure Gauge

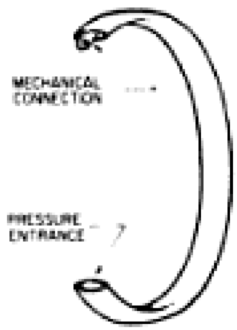


FIGURE 17–2 A bourdon tube.

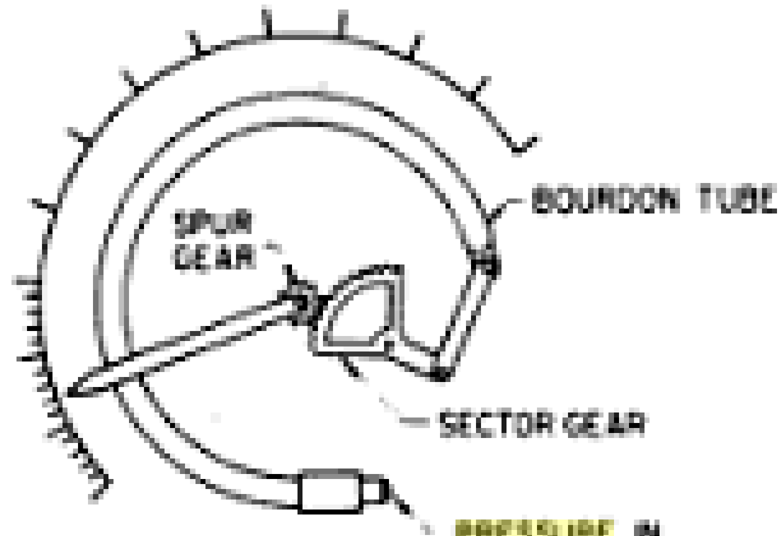


FIGURE 17–3 Bourdon-tube instrument mechanism.

Hydraulic Pressure Gauge

- A pressure gauge to measure the differential pressure in the hydraulic system indicates how this system is functioning.
- Hydraulic pressure gauges are designed to indicate either the pressure of the complete system or the pressure of an individual unit in the system.
- The case of this gauge contains a Bourdon tube and a gear-and-pinion mechanism by which the Bourdon tube's motion is amplified and transferred to the pointer.
- The position of the pointer on the calibrated dial indicates the hydraulic pressure in p.s.i.

Hydraulic Pressure Gauge

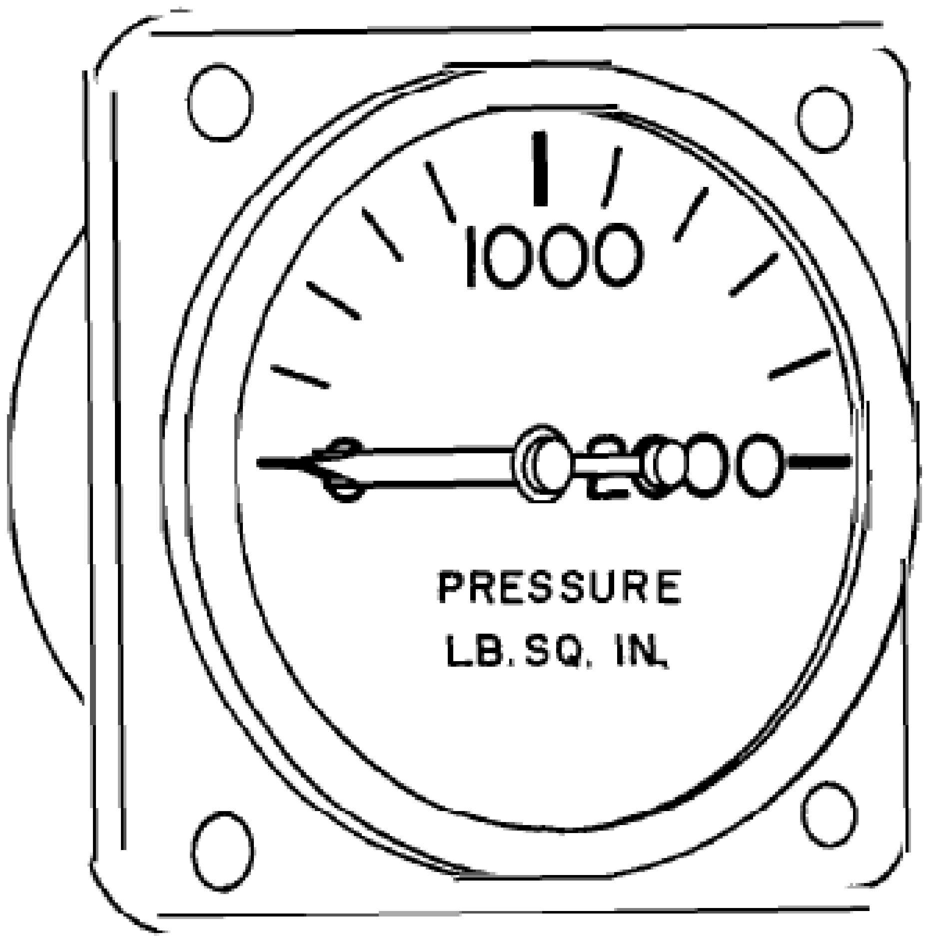


Figure 12–4. Hydraulic pressure gage

Diaphragm Type Pressure Gauge

- It is a differential- pressure measuring device
- They use a diaphragm for measuring pressure
- The pressure or suction to be measured is admitted to the pressure-sensitive diaphragm through an opening in the back of the instrument case
- An opposing pressure, such as that of the atmosphere, is admitted through a vent in the case

Diaphragm Type Pressure Gauge

- The walls of the diaphragm are very thin, an increase of pressure will cause it to expand, and a decrease in pressure will cause it to contract.

- Any movement of the diaphragm is transferred to the pointer by means of the rocker shaft, sector, and pinion, which are connected to the front side of the diaphragm.

Diaphragm Type Pressure Gauge

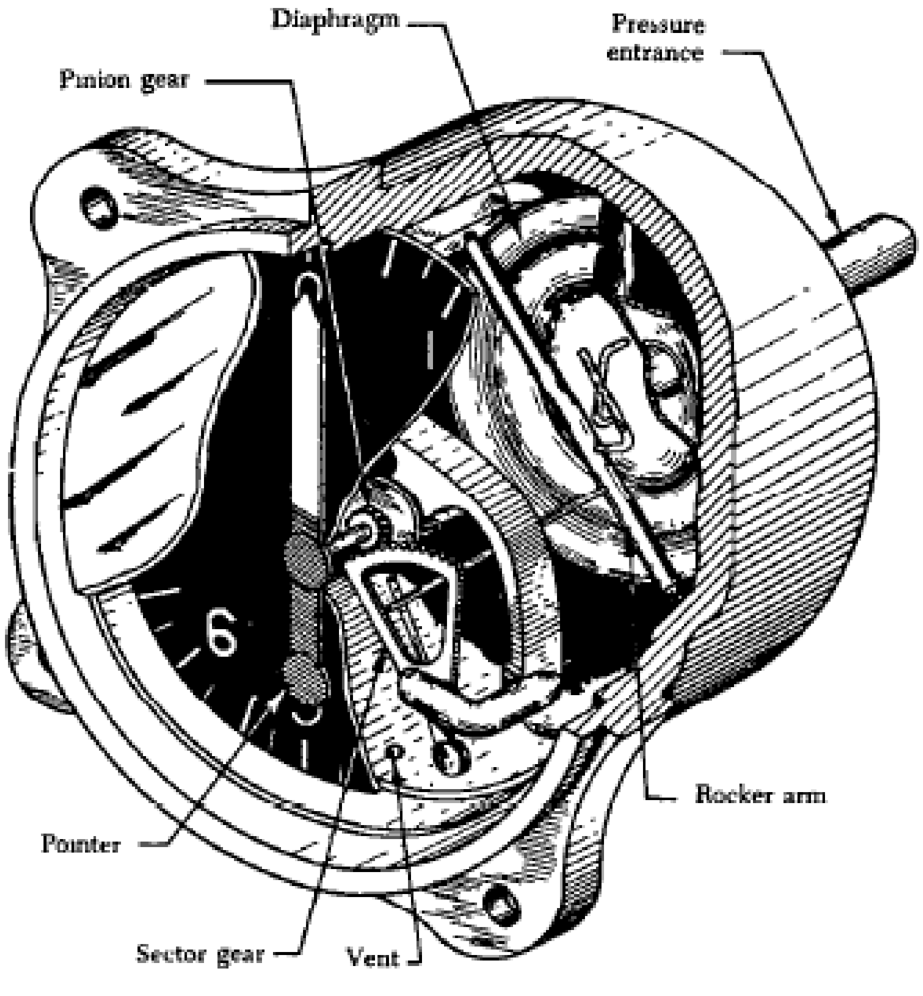


Figure 12–6. Diaphragm-type pressure gage.