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Volume 2

Aviation Maintenance Technician Handbook–Airframe, Volume 2

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Aviation Maintenance Technician Handbook–Airframe

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Volume Contents

Preface

The Aviation Maintenance Technician Handbook–Airframe (FAA-H-8083-31A) is one of a series of three handbooks for persons preparing for certification as an airframe or powerplant mechanic. It is intended that this handbook provide the basic information on principles, fundamentals, and technical procedures in the subject matter areas relating to the airframe rating. It is designed to aid students enrolled in a formal course of instruction, as well as the individual who is studying on his or her own. Since the knowledge requirements for the airframe and powerplant ratings closely parallel each other in some subject areas, the chapters which discuss fire protection systems and electrical systems contain some material which is also duplicated in the Aviation Maintenance Technician Handbook–Powerplant (FAA-H-8083-32A).

This volume contains information on airframe construction features, assembly and rigging, fabric covering, structural repairs, and aircraft welding. The handbook also contains an explanation of the units that make up the various airframe systems. Because there are so many different types of aircraft in use today, it is reasonable to expect that differences exist in airframe components and systems. To avoid undue repetition, the practice of using representative systems and units is carried out throughout the handbook. Subject matter treatment is from a generalized point of view and should be supplemented by reference to manufacturer's manuals or other textbooks if more detail is desired. This handbook is not intended to replace, substitute for, or supersede official regulations or the manufacturer's instructions. Occasionally the word "must" or similar language is used where the desired action is deemed critical. The use of such language is not intended to add to, interpret, or relieve a duty imposed by Title 14 of the Code of Federal Regulations (14 CFR).

This handbook is available for download, in PDF format, from www.faa.gov.

The subject of Human Factors is contained in the Aviation Maintenance Technician Handbook–General (FAA-H-8083-30).

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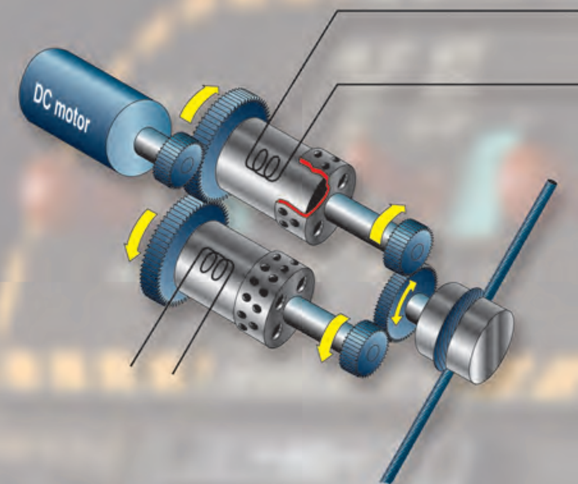
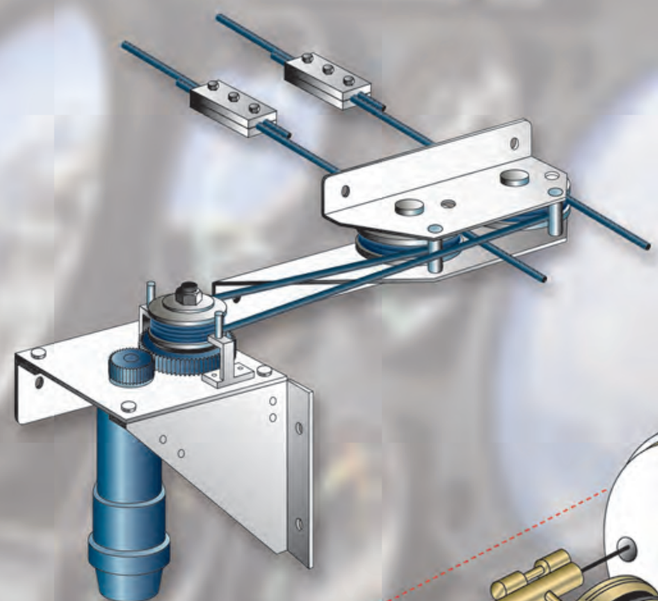
Chapter 10

Aircraft Instrument Systems





Introduction

Since the beginning of manned flight, it has been recognized that supplying the pilot with information about the aircraft and its operation could be useful and lead to safer flight. The Wright Brothers had very few instruments on their Wright Flyer, but they did have an engine tachometer, an anemometer (wind meter), and a stop watch. They were obviously concerned about the aircraft's engine and the progress of their flight. From that simple beginning, a wide variety of instruments have been developed to inform flight crews of different parameters. Instrument systems now exist to provide information on the condition of the aircraft, engine, components, the aircraft's attitude in the sky, weather, cabin environment, navigation, and communication. *Figure 10-1* shows various instrument panels from the Wright Flyer to a modern jet airliner.

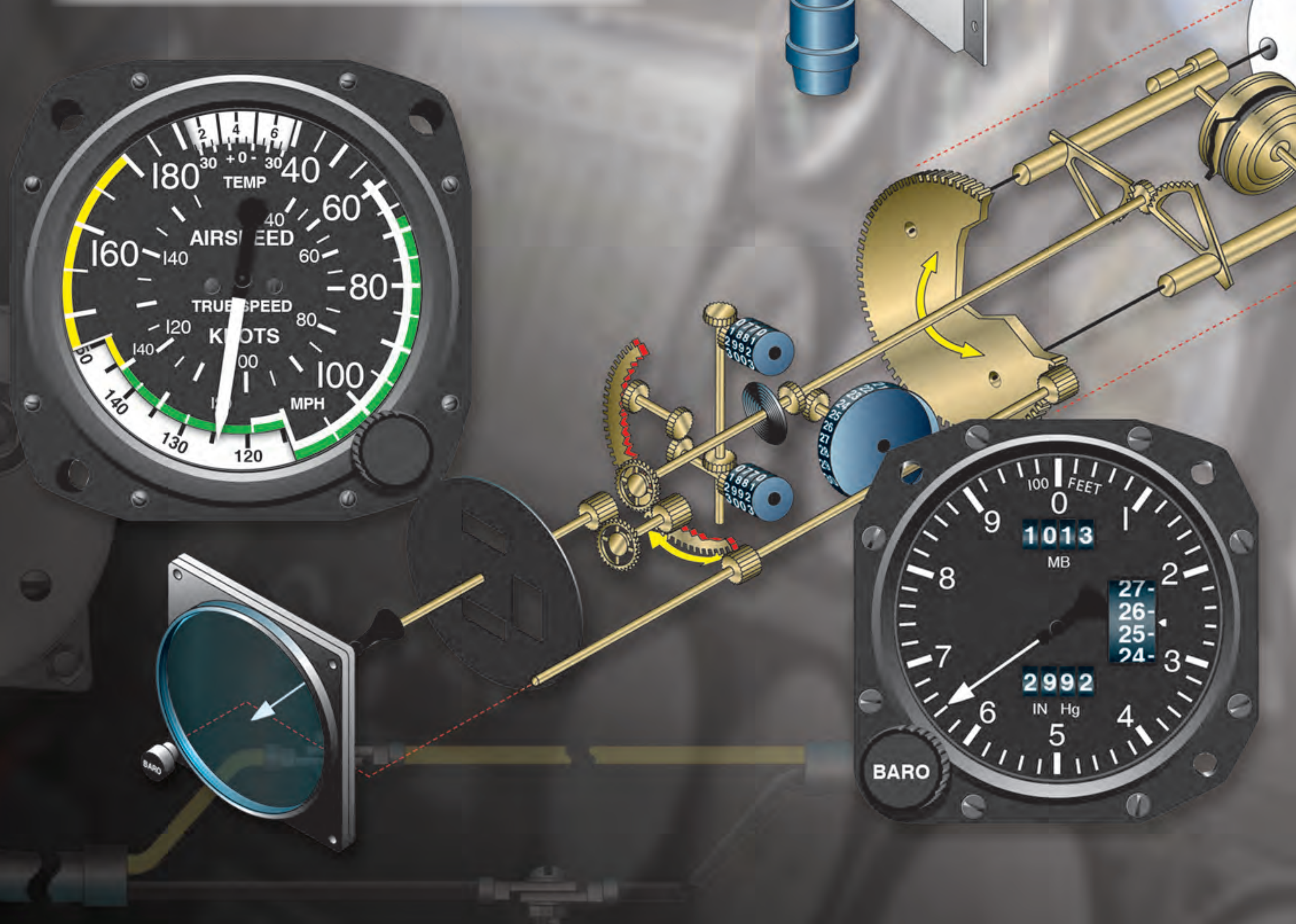


Figure 10-1. *From top to bottom: instruments of the Wright Flyer, instruments on a World War I era aircraft, a late 1950s/early 1960s Boeing 707 airliner cockpit, and an Airbus A380 glass cockpit.*

The ability to capture and convey all of the information a pilot may want, in an accurate, easily understood manner, has been a challenge throughout the history of aviation. As the range of desired information has grown, so too have the size and complexity of modern aircraft, thus expanding even further the need to inform the flight crew without sensory overload or overcluttering the cockpit. As a result, the old flat panel in the front of the cockpit with various individual instruments attached to it has evolved into a sophisticated computer-controlled digital interface with flat-panel display screens and prioritized messaging. A visual comparison between a conventional cockpit and a glass cockpit is shown in *Figure 10-2.*

There are usually two parts to any instrument or instrument system. One part senses the situation and the other part displays it. In analog instruments, both of these functions often take place in a single unit or instrument (case). These are called direct-sensing instruments. Remote-sensing requires the information to be sensed, or captured, and then sent to a

Figure 10-2. *A conventional instrument panel of the C-5A Galaxy (top) and the glass cockpit of the C-5B Galaxy (bottom).*

separate display unit in the cockpit. Both analog and digital instruments make use of this method. *[Figure 10-3]*

The relaying of important bits of information can be done in various ways. Electricity is often used by way of wires that carry sensor information into the cockpit. Sometimes pneumatic lines are used. In complex, modern aircraft, this can lead to an enormous amount of tubing and wiring terminating behind the instrument display panel. More efficient information transfer has been accomplished via the use of digital data buses. Essentially, these are wires that share message carrying for many instruments by digitally encoding the signal for each. This reduces the number of wires and weight required to transfer remotely sensed information for the pilot's use. Flat-panel computer display screens that can be controlled to show only the information desired are also lighter in weight than the numerous individual gauges it would take to display the same information simultaneously. An added bonus is the increased reliability inherent in these solid-state systems.

It is the job of the aircraft technician to understand and maintain all aircraft, including these various instrument systems. Accordingly, in this chapter, discussions begin with analog instruments and refer to modern digital instrumentation when appropriate.

Classifying Instruments

There are three basic kinds of instruments classified by the job they perform: flight instruments, engine instruments, and navigation instruments. There are also miscellaneous gauges and indicators that provide information that do not fall into these classifications, especially on large complex aircraft. Flight control position, cabin environmental systems, electrical power, and auxiliary power units (APUs), for example, are all monitored and controlled from the cockpit via the use of instruments systems. All may be regarded as position/condition instruments since they usually report the position of a certain moveable component on the aircraft, or the condition of various aircraft components or systems not included in the first three groups.

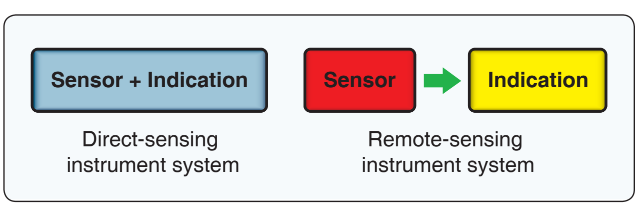


Figure 10-3. *There are two parts to any instrument system—the sensing mechanism and the display mechanism.*

Flight Instruments

The instruments used in controlling the aircraft's flight attitude are known as the flight instruments. 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. Much variation exists for these instruments, which is explained throughout this chapter. Over the years, flight instruments have come to be situated similarly on the instrument panels in most aircraft. 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).

Original analog flight instruments are operated by air pressure and the use of gyroscopes. This avoids the use of electricity, which could put the pilot in a dangerous situation if the aircraft lost electrical power. Development of sensing and display techniques, combined with advanced aircraft electrical systems, has made it possible for reliable primary and secondary instrument systems that are electrically operated. Nonetheless, often a pneumatic altimeter, a gyro artificial horizon, and a magnetic direction indicator are retained somewhere in the instrument panel for redundancy. *[Figure 10-5]*

Engine Instruments

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

Figure 10-4. *The basic T arrangement of analog flight instruments. At the bottom of the T is a heading indicator that functions as a compass but is driven by a gyroscope and not subject to the oscillations common to magnetic direction indicators.*

Figure 10-5. *This electrically operated flat screen display instrument panel, or glass cockpit, retains an analog airspeed indicator, a gyroscope-driven artificial horizon, and an analog altimeter as a backup should electric power be lost, or a display unit fails.*

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. *Figure 10-6* contains various engine instruments found on reciprocating and turbine-powered aircraft.

Engine instrumentation is often displayed in the center of the cockpit where it is easily visible to the pilot and copilot. *[Figure 10-7]* On light aircraft requiring only one flight crewmember, this may not be the case. Multiengine aircraft often use a single gauge for a particular engine parameter, but it displays information for all engines through the use of multiple pointers on the same dial face.

Navigation Instruments

Navigation instruments are those that contribute information used by the pilot to guide the aircraft along a definite course. 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. Other navigational instruments are designed specifically to direct the pilot's approach to landing at an

Reciprocating engines	Turbine engines
Oil pressure	Oil pressure
Oil temperature	Exhaust gas temperature (EGT)
Cylinder head temperature (CHT)	Turbine inlet temperature (TIT) or turbine gas temperature (TGT)
Manifold pressure	Engine pressure ratio (EPR)
Fuel quantity	Fuel quantity
Fuel pressure	Fuel pressure
	Fuel flow
Tachometer	Tachometer (percent calibrated)
	N_1 and N_2 compressor speeds
Carburetor temperature	Torquemeter (on turboprop and turboshaft engines)

Figure 10-6. *Common engine instruments. Note: For example purposes only. Some aircraft may not have these instruments or may be equipped with others.*

Figure 10-7. *An engine instrumentation located in the middle of the instrument panel is shared by the pilot and co-pilot.*

airport. Traditional navigation instruments include a clock and a magnetic compass. Along with the airspeed indicator and wind information, these can be used to calculate navigational progress. Radios and instruments sending locating information via radio waves have replaced these manual efforts in modern aircraft. Global position systems (GPS) use satellites to pinpoint the location of the aircraft via geometric triangulation. This technology is built into some aircraft instrument packages for navigational purposes. Many of these aircraft navigational systems are discussed in chapter 11 of this handbook. *[Figure 10-8]*

To understand how various instruments work and can be repaired and maintained, they can be classified according to the principle upon which they operate. Some use mechanical methods to measure pressure and temperature. Some utilize magnetism and electricity to sense and display a parameter. Others depend on the use of gyroscopes in their primary workings. Still others utilize solid state sensors and computers to process and display important information. In the following sections, the different operating principles for sensing parameters are explained. Then, an overview of many of the engine, flight, and navigation instruments is given.

Pressure Measuring Instruments

A number of instruments inform the pilot of the aircraft's condition and flight situations through the measurement of pressure. Pressure-sensing instruments can be found in the flight group and the engine group. They can be either direct reading or remote sensing. These are some of the most critical instruments on the aircraft and must accurately inform the pilot to maintain safe operations. Pressure measurement involves some sort of mechanism that can sense changes in pressure. A technique for calibration and displaying the information is then added to inform the pilot. The type of pressure needed to be measured often makes one sensing mechanism more suited for use in a particular instance. 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.

A Bourdon tube is illustrated in *Figure 10-9*. The open end of this coiled tube is fixed in place and the other end is sealed and free to move. When a fluid that needs to be measured is directed into the open end of the tube, the unfixed portion of the coiled tube tends to straighten out. The higher the pressure of the fluid, the more the tube straightens. When the pressure is reduced, the tube recoils. A pointer is attached to this moving end of the tube, usually through a linkage of small shafts and gears. By calibrating this motion of the straightening tube, a face or dial of the instrument can be created. Thus, by observing the pointer movement along the scale of the instrument face positioned behind it, pressure increases and decreases are communicated to the pilot.

The Bourdon tube is the internal mechanism for many pressure gauges used on aircraft. When high pressures need to be measured, the tube is designed to be stiff. Gauges used to

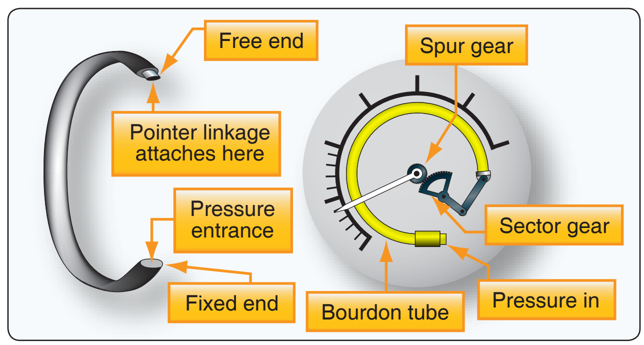


Figure 10-9. *The Bourdon tube is one of the basic mechanisms for sensing pressure.*

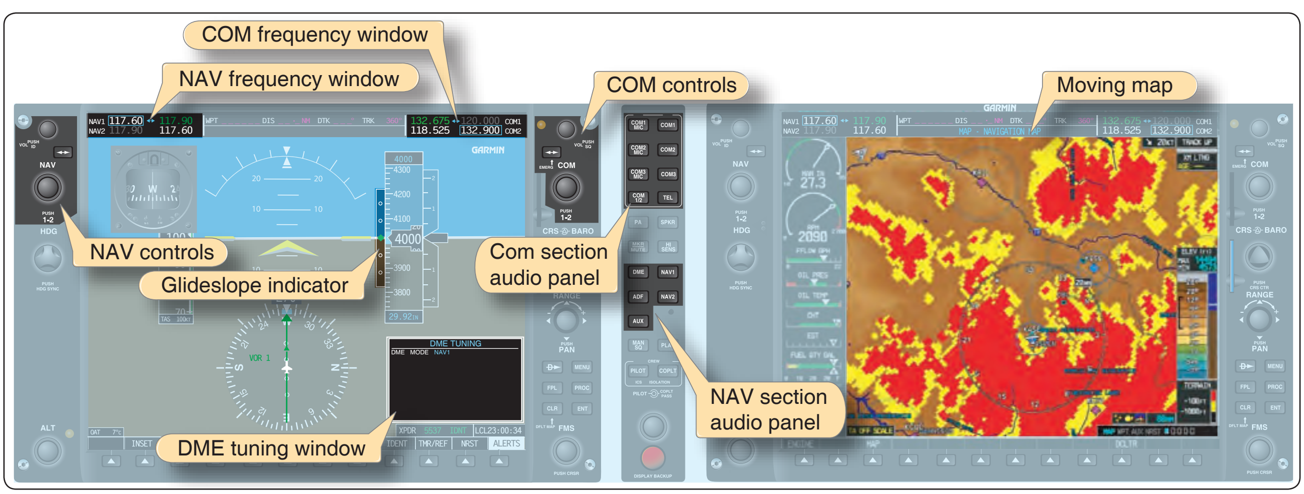


Figure 10-8. *Navigation instruments.*

indicate lower pressures use a more flexible tube that uncoils and coils more readily. Most Bourdon tubes are made from brass, bronze, or copper. Alloys of these metals can be made to coil and uncoil the tube consistently numerous times.

Bourdon tube gauges are simple and reliable. Some of the instruments that use a Bourdon tube mechanism include the engine oil pressure gauge, hydraulic pressure gauge, oxygen tank pressure gauge, and deice boot pressure gauge. Since the pressure of the vapor produced by a heated liquid or gas increases as temperature increases, Bourdon tube mechanisms can also be used to measure temperature. This is done by calibrating the pointer connecting linkage and relabeling the face of the gauge with a temperature scale. Oil temperature gauges often employ Bourdon tube mechanisms. *[Figure 10-10]*

Since the sensing and display of pressure or temperature information using a Bourdon tube mechanism usually occurs in a single instrument housing, they are most often direct reading gauges. But the Bourdon tube sensing device can also be used remotely. Regardless, it is necessary to direct the fluid to be measured into the Bourdon tube. For example, a common direct-reading gauge measuring engine oil pressure and indicating it to the pilot in the cockpit is mounted in the instrument panel. A small length of tubing connects a pressurized oil port on the engine, runs though the firewall, and into the back of the gauge. This setup is especially functional on light, single-engine aircraft in which the engine is mounted just forward of the instrument panel in the forward end of the fuselage. However, a remote sensing unit can be more practical on twin-engine aircraft where the engines are a long distance from the cockpit pressure display. Here, the Bourdon tube's motion is converted to an electrical signal and carried to the cockpit display via a wire. This is lighter and more efficient, eliminating the possibility of leaking fluids into the passenger compartment of the aircraft.

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

Diaphragms can also be sealed. The diaphragm can be evacuated before sealing, retaining absolutely nothing inside. When this is done, the diaphragm is called an aneroid. Aneroids are used in many flight instruments. A diaphragm can also be filled with a gas to standard atmospheric pressure and then sealed. Each of these diaphragms has their uses, which are described in the next section. The common factor

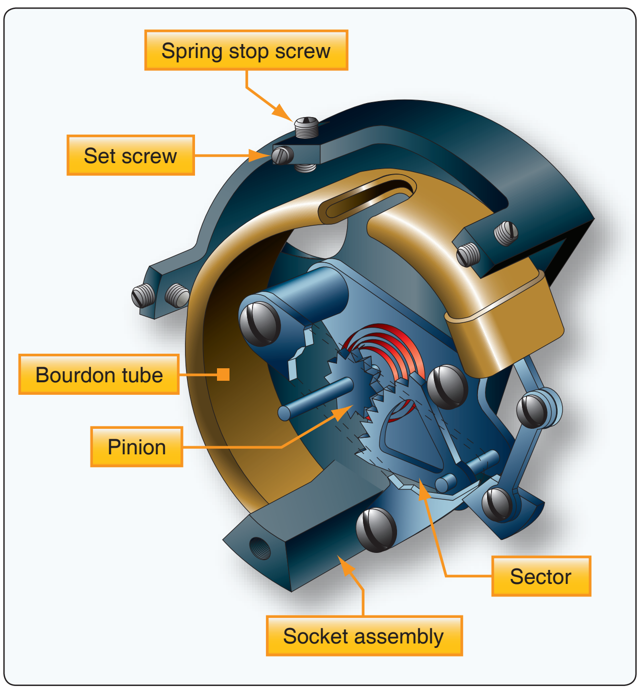


Figure 10-10. *The Bourdon tube mechanism can be used to measure pressure or temperature by recalibrating the pointer's connecting linkage and scaling instrument face to read in degrees Celsius or Fahrenheit.*

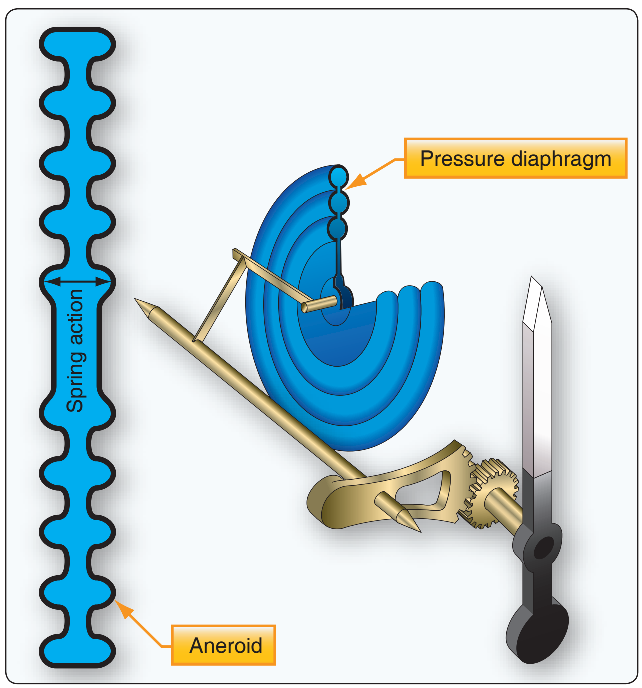


Figure 10-11. *A diaphragm used for measuring pressure. An evacuated sealed diaphragm is called an aneroid.*

in all is that the expansion and contraction of the side wall of the diaphragm is the movement that correlates to increasing and decreasing pressure.

When a number of diaphragm chambers are connected together, the device is called a bellows. This accordion-like assembly of diaphragms can be very useful when measuring the difference in pressure between two gases, called differential pressure. Just as with a single diaphragm, it is the movement of the side walls of the bellows assembly that correlates with changes in pressure and to which a pointer linkage and gearing is attached to inform the pilot. *[Figure 10-12]*

Diaphragms, aneroids, and bellows pressure sensing devices are often located inside the single instrument housing that contains the pointer and instrument dial read by the pilot on the instrument panel. Thus, many instruments that make use of these sensitive and reliable mechanisms are direct reading gauges. But, many remote sensing instrument systems also make use of the diaphragm and bellows. In this case, the sensing device containing the pressure sensitive diaphragm or bellows is located remotely on the engine or airframe. It is part of a transducer that converts the pressure into an electrical signal. The transducer, or transmitter, sends the signal to the gauge in the cockpit, or to a computer, for processing and subsequent display of the sensed condition. Examples of instruments that use a diaphragm or bellows in a direct reading or remote sensing gauge are the altimeter, vertical speed indicator, cabin differential pressure gauge (in pressurized aircraft), and manifold pressure gauge.

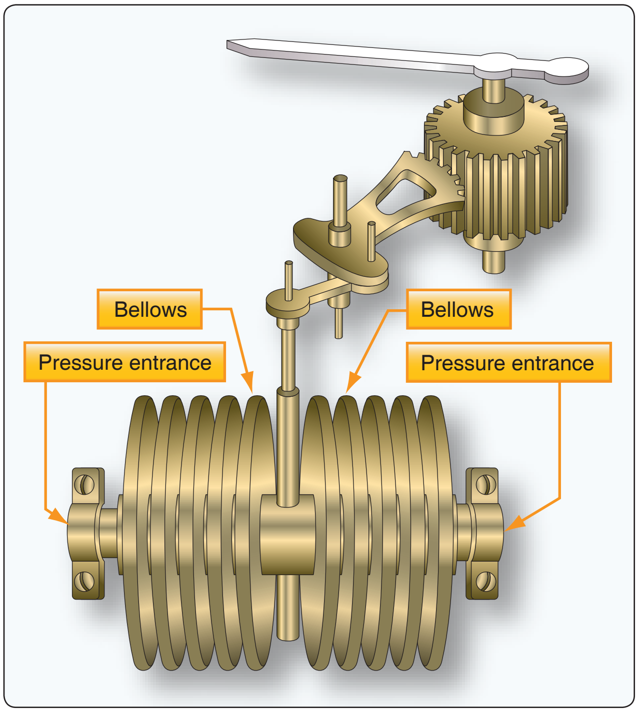


Figure 10-12. *A bellows unit in a differential pressure gauge compares two different pressure values. End movement of the bellows away from the side with the highest pressure input occurs when the pressures in the bellows are not equal. The indicator linkage is calibrated to display the difference.*

Solid-state microtechnology pressure sensors are used in modern aircraft to determine the critical pressures needed for safe operation. Many of these have digital output ready for processing by electronic flight instrument computers and other onboard computers. Some sensors send microelectric signals that are converted to digital format for use by computers. As with the analog sensors described above, the key to the function of solid-state sensors is their consistent property changes as pressure changes.

The solid-state sensors used in most aviation applications exhibit varying electrical output or resistance changes when pressure changes occur. Crystalline piezoelectric, piezoresistor, and semiconductor chip sensors are most common. In the typical sensor, tiny wires are embedded in the crystal or pressure-sensitive semiconductor chip. When pressure deflects the crystal(s), a small amount of electricity is created or, in the case of a semiconductor chip and some crystals, the resistance changes. Since the current and resistance changes vary directly with the amount of deflection, outputs can be calibrated and used to display pressure values.

Nearly all of the pressure information needed for engine, airframe, and flight instruments can be captured and/or calculated through the use of solid-state pressure sensors in combination with temperature sensors. But continued use of aneroid devices for comparisons involving absolute pressure is notable. Solid-state pressure-sensing systems are remote sensing systems. The sensors are mounted on the aircraft at convenient and effective locations.

Types of Pressure

Pressure is a comparison between two forces. Absolute pressure exists when a force is compared to a total vacuum, or absolutely no pressure. It is necessary to define absolute pressure, because the air in the atmosphere is always exerting pressure on everything. Even when it seems there is no pressure being applied, like when a balloon is deflated, there is still atmospheric pressure inside and outside of the balloon. To measure that atmospheric pressure, it is necessary to compare it to a total absence of pressure, such as in a vacuum. Many aircraft instruments make use of absolute pressure values, such as the altimeter, the rate-of-climb indicator, and the manifold pressure gauge. As stated, this is usually done with an aneroid.

The most common type of pressure measurement is gauge pressure. This is the difference between the pressure to be measured and the atmospheric pressure. The gauge pressure inside the deflated balloon mentioned above is therefore 0 pounds per square inch (psi). Gauge pressure is easily measured and is obtained by ignoring the fact that the atmosphere is always exerting its pressure on everything. For example, a tire is filled with air to 32 psi at a sea level location and checked with a gauge to read 32 psi, which is the gauge pressure. The approximately 14.7 psi of air pressing on the outside of the tire is ignored. The absolute pressure in the tire is 32 psi plus the 14.7 psi that is needed to balance the 14.7 psi on the outside of the tire. So, the tire's absolute pressure is approximately 46.7 psi. If the same tire is inflated to 32 psi at a location 10,000 feet above sea level, the air pressure on the outside of the tire would only be approximately 10 psi, due to the thinner atmosphere. The pressure inside the tire required to balance this would be 32 psi plus 10 psi, making the absolute pressure of the tire 42 psi. So, the same tire with the same amount of inflation and performance characteristics has different absolute pressure values. Gauge pressure, however, remains the same, indicating the tires are inflated identically. It this case, gauge pressure is more useful in informing us of the condition of the tire.

Gauge pressure measurements are simple and widely useful. They eliminate the need to measure varying atmospheric pressure to indicate or monitor a particular pressure situation. Gauge pressure should be assumed, unless otherwise indicated, or unless the pressure measurement is of a type known to require absolute pressure.

In many instances in aviation, it is desirable to compare the pressures of two different elements to arrive at useful information for operating the aircraft. When two pressures are compared in a gauge, the measurement is known as differential pressure and the gauge is a differential pressure gauge. An aircraft's airspeed indicator is a differential pressure gauge. It compares ambient air pressure with ram air pressure to determine how fast the aircraft is moving through the air. A turbine's engine pressure ratio (EPR) gauge is also a differential pressure gauge. It compares the pressure at the inlet of the engine with that at the outlet to indicate the thrust developed by the engine. Both of these differential pressure gauges and others are discussed further in this chapter and throughout this handbook.

In aviation, there is also a commonly used pressure known as standard pressure. Standard pressure refers to an established or standard value that has been created for atmospheric pressure. This standard pressure value is 29.92 inches of mercury ("Hg), 1,013.2 hectopascal (hPa), or 14.7 psi. It is part of a standard day that has been established that includes a standard temperature of 15 °C at sea level. Specific standard day values have also been established for air density, volume, and viscosity. All of these values are developed averages since the atmosphere is continuously fluctuating. They are used by engineers when designing instrument systems and are sometimes used by technicians and pilots. Often, using a standard value for atmospheric pressure is more desirable than using the actual value. For example, at 18,000 feet and above, all aircraft use 29.92 "Hg as a reference pressure for their instruments to indicate altitude. This results in altitude indications in all cockpits being identical. Therefore, an accurate means is established for maintaining vertical separation of aircraft flying at these high altitudes.

Pressure Instruments

Engine Oil Pressure

The most important instrument used by the pilot to perceive the health of an engine is the engine oil pressure gauge. *[Figure 10-13]* Oil pressure is usually indicated in psi. The normal operating range is typically represented by a green arc on the circular gauge. For exact acceptable operating range, consult the manufacturer's operating and maintenance data. In reciprocating and turbine engines, oil is used to lubricate and cool bearing surfaces where parts are rotating or sliding past each other at high speeds. A loss of pressurized oil to these areas would rapidly cause excessive friction and over temperature conditions, leading to catastrophic engine failure. As mentioned, aircraft using analog instruments often use direct reading Bourdon tube oil pressure gauges.

Figure 10-13. *An analog oil pressure gauge is driven by a Bourdon tube. Oil pressure is vital to engine health and must be monitored by the pilot.*

Figure 10-13 shows the instrument face of a typical oil pressure gauge of this type. Digital instrument systems use an analog or digital remote oil pressure sensing unit that sends output to the computer, driving the display of oil pressure value(s) on the aircraft's cockpit display screens. Oil pressure may be displayed in a circular or linear gauge fashion and may even include a numerical value on screen. Often, oil pressure is grouped with other engine parameter displays on the same page or portion of a page on the display. *Figure 10-14* shows this grouping on a Garmin G1000 digital instrument display system for general aviation aircraft.

Manifold Pressure

In reciprocating engine aircraft, the manifold pressure gauge indicates the pressure of the air in the engine's induction manifold. This is an indication of power being developed by the engine. The higher the pressure of the fuel air mixture going into the engine, the more power it can produce. For normally aspirated engines, this means that an indication near atmospheric pressure is the maximum. Turbocharged or supercharged engines pressurize the air being mixed with the fuel, so full power indications are above atmospheric pressure.

Most manifold pressure gauges are calibrated in inches of mercury, although digital displays may have the option to display in a different scale. A typical analog gauge makes use of an aneroid described above. When atmospheric pressure acts on the aneroid inside the gauge, the connected pointer indicates the current air pressure. A line running from the intake manifold into the gauge presents intake manifold air pressure to the aneroid, so the gauge indicates the absolute pressure in the intake manifold. An analog manifold pressure gauge, along with its internal workings, is shown in *Figure 10-15*. The digital presentation of manifold pressure is at the top of the engine instruments displayed on the Garmin G1000 multifunctional display in *Figure 10-14*. The aircraft's operating manual contains data on managing manifold pressure in relation to fuel flow and propeller pitch and for achieving various performance profiles during different phases of run-up and flight.

Engine Pressure Ratio (EPR)

Turbine engines have their own pressure indication that relates the power being developed by the engine. It is called the engine pressure ratio (EPR) indicator (EPR gauge). This

Figure 10-14. *Oil pressure indication with other engine-related parameters shown in a column on the left side of this digital cockpit display panel.*

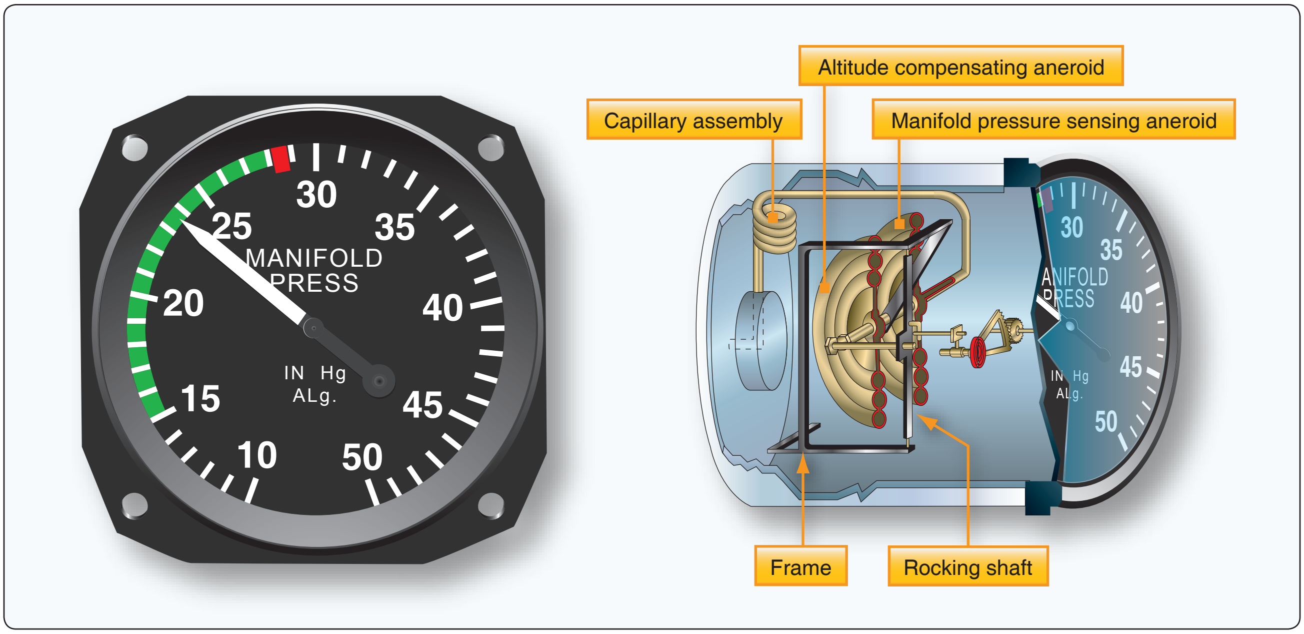


Figure 10-15. *An analog manifold pressure indicator instrument dial calibrated in inches of mercury (left). The internal workings of an analog manifold pressure gauge are shown on the right. Air from the intake manifold surrounds the aneroid causing it to deflect and indicate pressure on the dial through the use of linkage to the pointer (right).*

gauge compares the total exhaust pressure to the pressure of the ram air at the inlet of the engine. With adjustments for temperature, altitude, and other factors, the EPR gauge presents an indication of the thrust being developed by the engine. Since the EPR gauge compares two pressures, it is a differential pressure gauge. It is a remote-sensing instrument that receives its input from an engine pressure ratio transmitter or, in digital instrument systems displays, from a computer. The pressure ratio transmitter contains the bellows arrangement that compares the two pressures and converts the ratio into an electric signal used by the gauge for indication. *[Figure 10-16]*

Fuel Pressure

Fuel pressure gauges also provide critical information to the pilot. *[Figure 10-17]* Typically, fuel is pumped out of various fuel tanks on the aircraft for use by the engines. A malfunctioning fuel pump, or a tank that has been emptied beyond the point at which there is sufficient fuel entering the pump to maintain desired output pressure, is a condition that requires the pilot's immediate attention. While direct-sensing fuel pressure gauges using Bourdon tubes, diaphragms, and bellows sensing arrangements exist, it is particularly undesirable to run a fuel line into the cockpit,

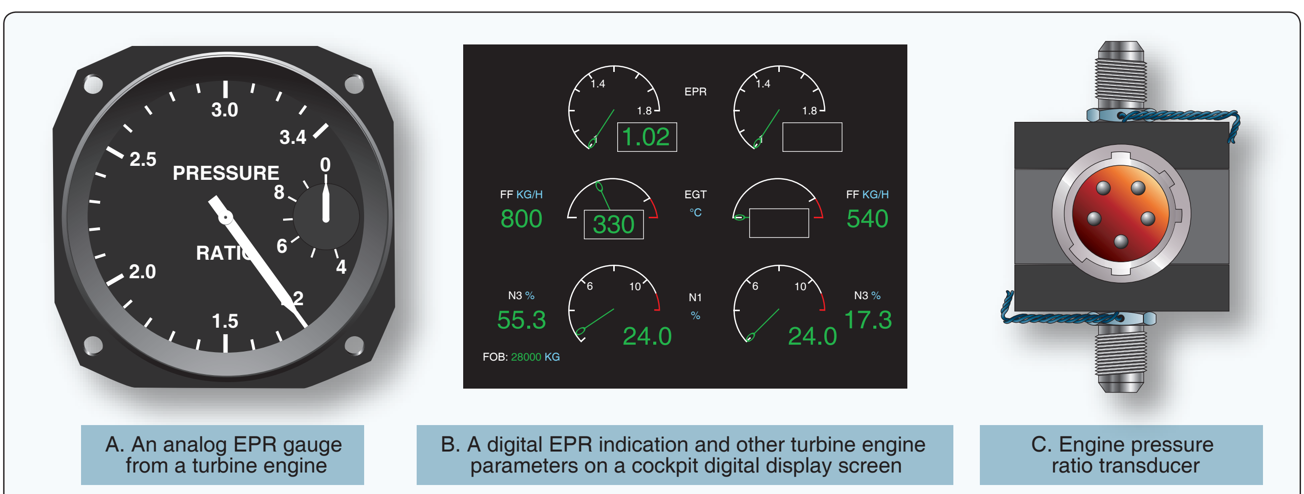


Figure 10-16. *Engine pressure ratio gauges.*

Figure 10-17. *A typical analog fuel pressure gauge.*

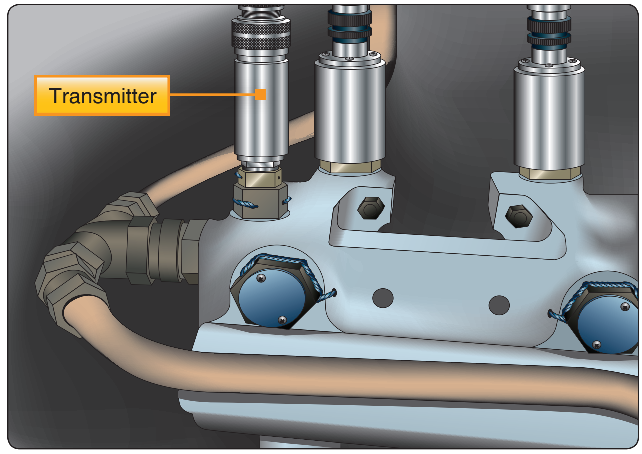


Figure 10-18. *A hydraulic pressure transmitter senses and converts pressure into an electrical output for indication by the cockpit gauge or for use by a computer that analyzes and displays the pressure in the cockpit when requested or required.*

due to the potential for fire should a leak develop. Therefore, the preferred arrangement is to have whichever sensing mechanism that is used be part of a transmitter device that uses electricity to send a signal to the indicator in the cockpit. Sometimes, indications monitoring the fuel flow rate are used instead of fuel pressure gauges. Fuel flow indications are discussed in the fuel system chapter of this handbook.

Hydraulic Pressure

Numerous other pressure monitoring gauges are used on complex aircraft to indicate the condition of various support systems not found on simple light aircraft. Hydraulic systems are commonly used to raise and lower landing gear, operate flight controls, apply brakes, and more. Sufficient pressure in the hydraulic system developed by the hydraulic pump(s) is required for normal operation of hydraulic devices. Hydraulic pressure gauges are often located in the cockpit and at or near the hydraulic system servicing point on the airframe. Remotely located indicators used by maintenance personnel are almost always direct reading Bourdon tube type gauges. Cockpit gauges usually have system pressure transmitted from sensors or computers electrically for indication. *Figure 10-18* shows a hydraulic pressure transmitter in place in a high-pressure aircraft hydraulic system.

Vacuum Pressure

Gyro pressure gauge, vacuum gauge, or suction gauge are all terms for the same gauge used to monitor the vacuum developed in the system that actuates the air driven gyroscopic flight instruments. Air is pulled through the instruments, causing the gyroscopes to spin. The speed at which the gyros spin needs to be within a certain range for correct operation. This speed is directly related to the suction pressure that is developed in the system. The suction gauge is extremely important in aircraft relying solely on vacuum-operated gyroscopic flight instruments.

Vacuum is a differential pressure indication, meaning the pressure to be measured is compared to atmospheric pressure through the use of a sealed diaphragm or capsule. The gauge is calibrated in inches of mercury. It shows how much less pressure exists in the system than in the atmosphere. *Figure 10-19* shows a suction gauge calibrated in inches of mercury.

Pressure Switches

In aviation, it is often sufficient to simply monitor whether the pressure developed by a certain operating system is too high or too low, so that an action can take place should one of these conditions occur. This is often accomplished through the use of a pressure switch. A pressure switch is a simple device usually made to open or close an electric circuit when a certain pressure is reached in a system. It can be manufactured so that the electric circuit is normally open and can then close when a certain pressure is sensed, or the circuit can be closed and then opened when the activation pressure is reached. [*Figure 10-20]*

Pressure switches contain a diaphragm to which the pressure being sensed is applied on one side. The opposite side of the diaphragm is connected to a mechanical switching mechanism for an electric circuit. Small fluctuations or a buildup of pressure against the diaphragm move the diaphragm, but not enough to throw the switch. Only when

Figure 10-19. *Vacuum suction gauge.*

Figure 10-20. *A pressure switch can be used in addition to, or instead of, a pressure gauge.*

pressure meets or exceeds a preset level designed into the structure of the switch does the diaphragm move far enough for the mechanical device on the opposite side to close the switch contacts and complete the circuit. *[Figure 10-21]* Each switch is rated to close (or open) at a certain pressure and must only be installed in the proper location.

A low oil pressure indication switch is a common example of how pressure switches are employed. It is installed in an engine so pressurized oil can be applied to the switch's

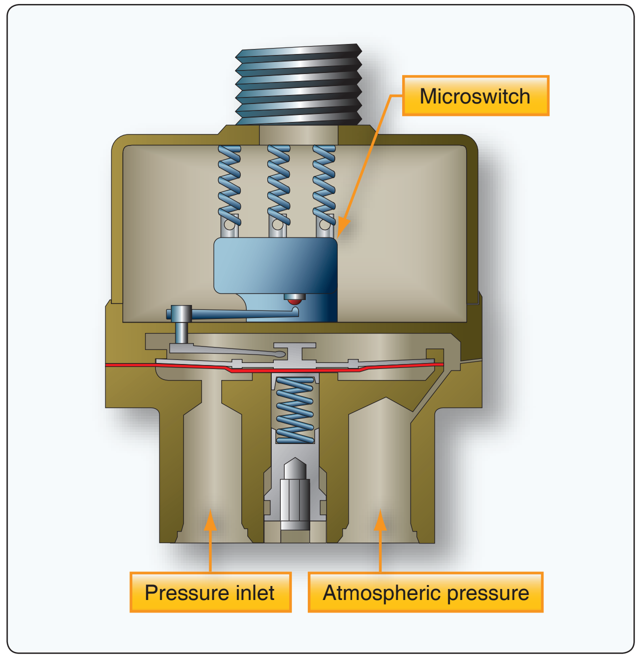


Figure 10-21. *A normally open pressure switch positioned in an electrical circuit causes the circuit to be open as well. The switch closes, allowing electricity to flow when pressure is applied beyond the switch's preset activation point. Normally, closed pressure switches allow electricity to flow through the switch in a circuit but open when pressure reaches a preset activation point, thus opening the electrical circuit.*

diaphragm. Upon starting the engine, oil pressure increases and the pressure against the diaphragm is sufficient to hold the contacts in the switch open. As such, current does not flow through the circuit and no indication of low oil pressure is given in the cockpit. Should a loss of oil pressure occur, the pressure against the diaphragm becomes insufficient to hold the switched contacts open. When the contacts close, they close the circuit to the low oil pressure indicator, usually a light, to warn the pilot of the situation.

Pressure gauges for various components or systems work similarly to those mentioned above. Some sort of sensing device, appropriate for the pressure being measured or monitored, is matched with an indicating display system. If appropriate, a properly rated pressure switch is installed in the system and wired into an indicating circuit. Further discussion of specific instruments occurs throughout this handbook as the operation of various systems and components are discussed.

Pitot-Static Systems

Some of the most important flight instruments derive their indications from measuring air pressure. Gathering and distributing various air pressures for flight instrumentation is the function of the pitot-static system.

Pitot Tubes and Static Vents

On simple aircraft, this may consist of a pitot-static system head or pitot tube with impact and static air pressure ports and leak-free tubing connecting these air pressure pick-up points to the instruments that require the air for their indications. The altimeter, airspeed indicator, and vertical speed indicator are the three most common pitot-static instruments. *Figure 10-22* illustrates a simple pitot-static system connected to these three instruments.

A pitot tube is open and faces into the airstream to receive the full force of the impact air pressure as the aircraft moves forward. This air passes through a baffled plate designed to protect the system from moisture and dirt entering the tube. Below the baffle, a drain hole is provided, allowing moisture to escape. The ram air is directed aft to a chamber in the shark fin of the assembly. An upright tube, or riser, leads this pressurized air out of the pitot assemble to the airspeed indicator.

The aft section of the pitot tube is equipped with small holes on the top and bottom surfaces that are designed to collect air pressure that is at atmospheric pressure in a static, or still, condition. The static section also contains a riser tube and the air is run out the pitot assembly through tubes and

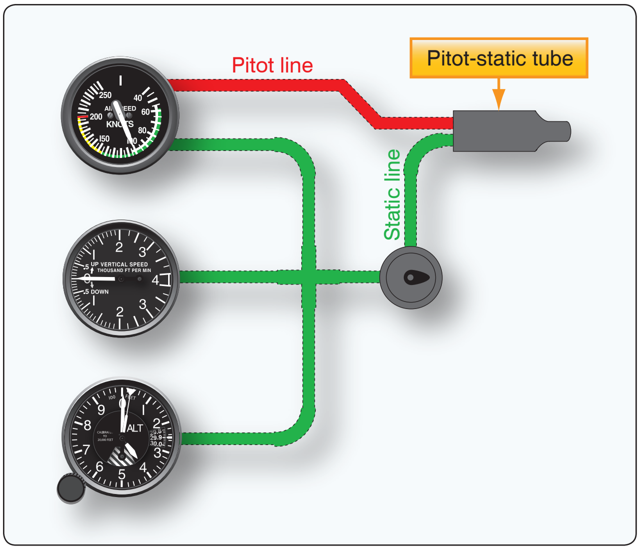


Figure 10-22. *A simple pitot-static system is connected to the primary flight instruments.*

is connected to the altimeter, the airspeed indicator, and the vertical speed indicator. *[Figure 10-23]*

Many pitot-static tube heads contain heating elements to prevent icing during flight. The pilot can send electric current

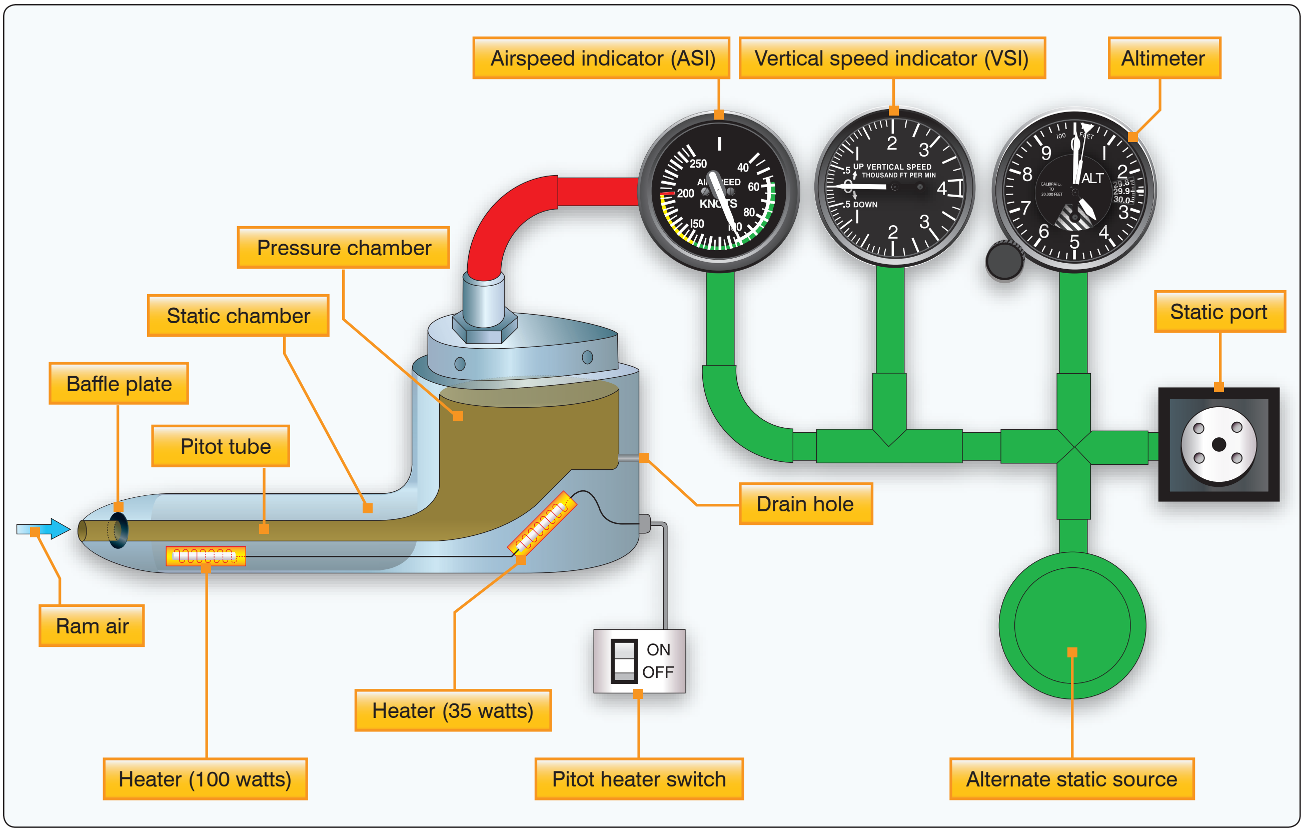


Figure 10-23. *A typical pitot-static system head, or pitot tube, collects ram air and static pressure for use by the flight instruments.*