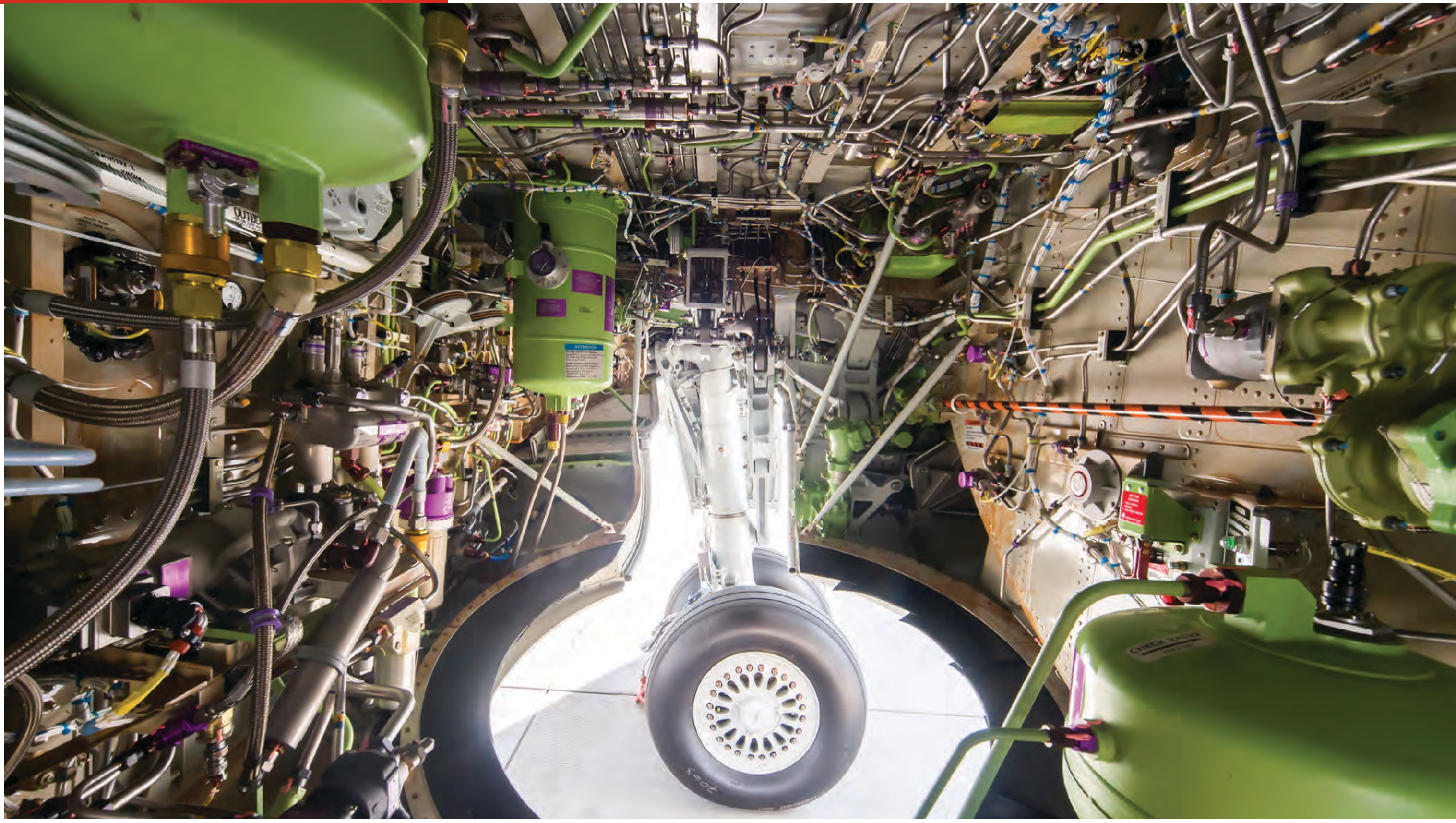
Aviation Mechanic Series

Original Text by Dale Crane

Airframe Systems

Fourth Edition



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Keith Anderson

Technical Editor

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NEWCASTLE, WASHINGTON

Aviation Mechanic Series: Airframe Systems
Fourth Edition
Based on the original text by Dale Crane

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None of the material in this book supersedes any operational documents or procedures issued by the Federal Aviation Administration, aircraft and avionics manufacturers, flight schools, or the operators of aircraft.

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Fourth Edition

Based on the original text by:

Dale Crane

Dale Crane was involved in aviation for more than 50 years. His credentials include Airframe and Powerplant Mechanic, Designated Mechanic Examiner, Commercial Pilot, Flight Instructor (airplanes), and Advanced and Instrument Ground Instructor.

Dale began his career in the U.S. Navy as a mechanic and flight engineer in patrol bombers (PBYs). After World War II, he attended Parks Air College. After college, he worked as an instrument overhaul mechanic, instrument shop manager, and flight test instrumentation engineer. He spent the following 16 years as an instructor and then became director of an aviation maintenance school.

For 30 years, Dale was active as a writer of aviation technical materials and a consultant in developing aviation training programs. He participated with the FAA in the Aviation Mechanic Occupation Study and the Aviation Mechanic Textbook Study. ATEC presented to Dale Crane their special recognition award for "his contribution to the development of aviation technicians as a prolific author of specialized maintenance publications."

Dale Crane also received the FAA's Charles Taylor "Master Mechanic" Award for 50 years of service in and contributions to the aviation maintenance industry, and the recognition of his peers for his excellence in aircraft maintenance as a leader, educator, and aviation safety advocate.

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Keith Anderson is an Associate Professor in the Applied Aviation Science Department in the College of Aviation and Aeronautical Science at LeTourneau University. He obtained his A&P certificate in 1983 and received his Inspection Authorization (IA) rating in 1997. He is a commercial pilot with Instrument Rating and is a certified flight instructor. He has an Associate Degree in Aviation Technology, a Bachelor of Science Degree in Electrical Engineering Technology, Aviation Option from LeTourneau University, and an MBA with Management Certificate from Corban University. He has been employed as a mechanic and director of maintenance at several maintenance facilities, including shops operating under Part 135 and Part 121. In addition to his maintenance experience, he flew for eight years for a non-profit mission organization in Venezuela and Guatemala and additionally served as chief inspector for one year for a non-governmental organization (NGO) in Uganda.

Following his overseas experiences, he was employed as a design engineer, director of engineering, and director of customer service for a company developing a new single-engine turboprop utility airplane, with additional duties as an Administrative Designated Engineering Representative (DER), and he was the primary point of contact with the FAA Aircraft Certification Office for the successful certification of the aircraft. Keith later became the vice president of engineering for a well-known company that developed supplemental type certificates (STCs) for corporate aircraft and also served as the director of engineering for an aircraft simulation company.

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Stephen Roth earned a B.S. (Engineering Physics) at Cornell University and M.S. (Applied Physics) at Stanford University, then worked for several years as an engineer in ultrahigh vacuum and radiation detection. He returned to school to earn an M.D. Following a many-decade hiatus from flying, he became a private pilot and proceeded to earn the CFI certificate. After retiring from medical practice, he returned to school at Embry-Riddle Aeronautical University to earn an A&P. For the past several years he has taught courses in AMT, Human Factors and Computer Science at ERAU and has earned his commercial glider and seaplane ratings. Recently he joined the Aerospace Engineering and Research Center at ERAU, Eagle Works as Associate Director.

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Peter Vosbury attended Embry-Riddle Aeronautical University from 1968 to 1969 and completed the airframe and powerplant certification program there. From 1970 to 1973 he served on the carrier *U.S.S. Forrestal* as a turbine engine mechanic for the U.S. Navy. After the Navy, Peter went back to school and completed a Masters Degree in Education at the University of Central Florida. In 1976 he began teaching at Embry-Riddle in the AMT Department and in 2000 transferred to the Air Science Department, now teaching turbine engines and aircraft systems to professional pilot students. Peter Vosbury is the author of several books covering topics in math and physics, aviation regulations, weight and balance, and turbine engines, and has also participated in writing answers and explanations to the FAA A&P exams.

AIRCRAFT ELECTRICAL SYSTEMS

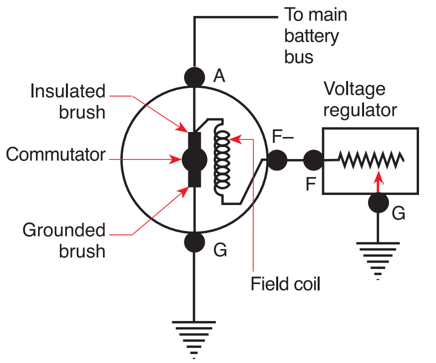
1

the components for use in aircraft. It is not permissible to use an automobile component in an FAA-certificated aircraft even though the parts do look alike.

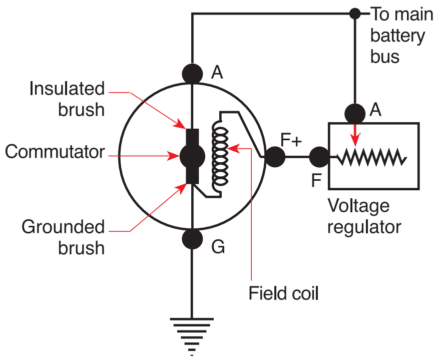
There are two types of generator circuits used in aircraft electrical systems. Both are shown in Figure 1-34. The A-circuit's field coils are connected to the insulated brush inside the generator, and the voltage regulator acts as a variable resistor between the generator field and ground. In the B-circuit, the field coils are connected to the grounded brush, and the voltage regulator acts as a variable resistor between the generator field and the armature. The electrical systems that use these two types of generators work in the same way. The only difference is in the connection and servicing of the two systems. The fact that the components used in these different types of systems look much alike makes it very important that you use only the correct part number for the component when servicing these systems.

The generator control contains three units: the voltage regulator, the current limiter, and the reverse-current cutout. This unit is shown in Figure 1-35 and is described in more detail in the *Powerplant* textbook of the Aviation Mechanic Series.

The voltage regulator senses the generator output voltage, and its normally closed contacts vibrate open and closed many times a second, limiting the



Voltage regulator used with A-circuit generator system is between shunt field and ground.



In B-circuit system, voltage regulator is between shunt field and armature.

Figure 1-34. *The placement of voltage regulators in the field circuits of generators for light aircraft.*

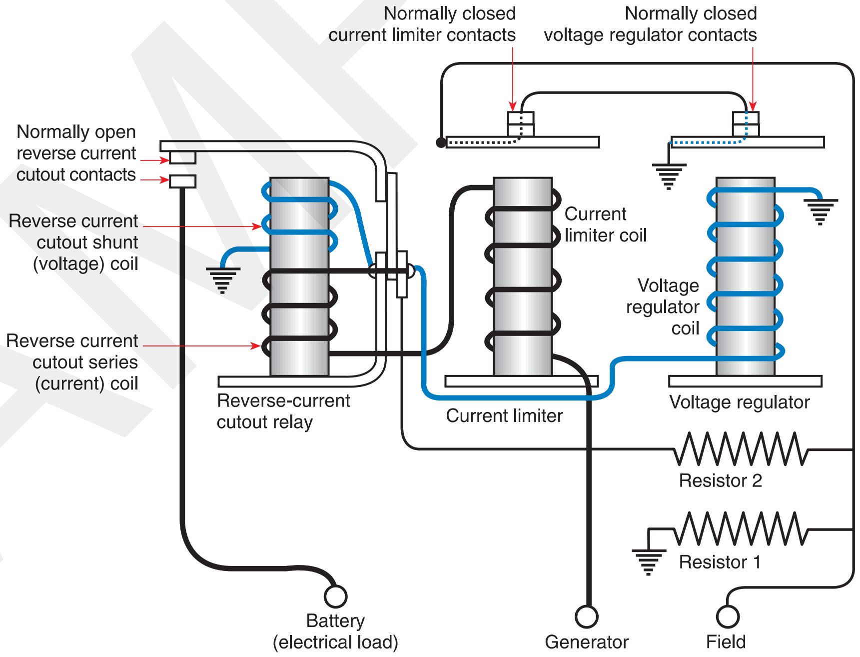


Figure 1-35. *An A-circuit, three-unit generator control such as is used on light aircraft.*

amount of current that can flow through the field. When the contacts are closed, the field current flows through the generator field coil, to ground through the contacts, and the output voltage increases. As the voltage increases, the magnetic field of the voltage regulator coil becomes strong enough to open the normally closed contacts, and the field current must then flow to ground through resistor 1. This increase in the field resistance decreases the field current and the generator output voltage drops enough to allow the contacts to close, repeating the cycle.

The current limiter is actuated by a coil in series with the armature output. When the generator puts out more than its rated current, the current limiter's normally closed contacts open and put a resistance in the field circuit to lower the generator output voltage to a level that will not produce excessive current.

The normally open contacts of the reverse-current cutout disconnect the generator from the aircraft bus when the generator voltage drops below that of the battery, and they automatically connect the generator to the bus when the generator voltage rises above that of the battery.

Simple Light-Aircraft Generator System

The A-circuit type generator system in Figure 1-36 is typical for most single-engine light airplanes.

The armature terminal of the generator connects to the G terminal of the generator control unit. The contacts of the reverse-current cutout are between the G and the B terminals. When the generator output reaches a specified voltage, the reverse-current cutout contacts close and connect the generator to the main bus.

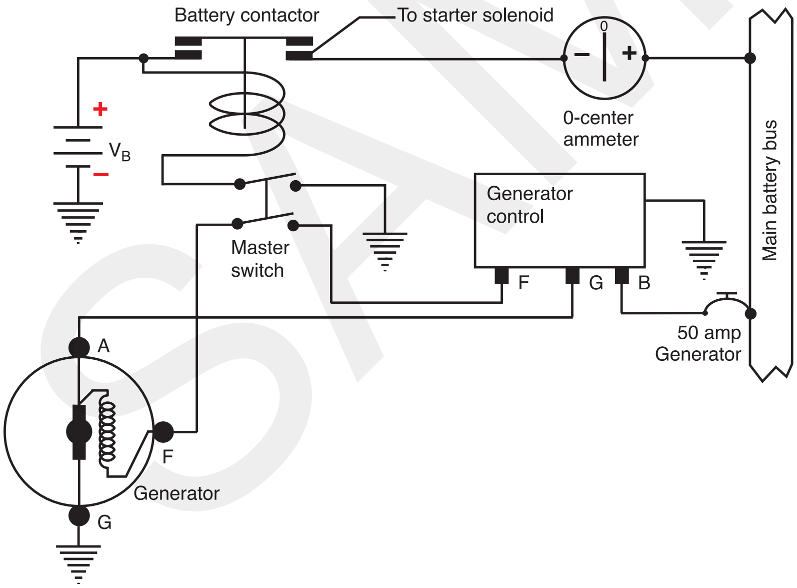


Figure 1-36. *Simple light-aircraft generator system.*

Field current produced in the generator flows from the field terminal of the generator, through the generator side of the master switch, into the F terminal of the control unit, and through the voltage regulator and current limiter contacts to ground. If either the voltage or the current are too high, one set of normally closed contacts opens and this field current must flow through the resistor to ground.

The zero-center ammeter shows the amount of current flowing either from the battery to the main bus (–) or from the generator through the main bus into the battery (+) to charge it.

Twin-Engine Generator System Using Vibrator-Type Voltage Regulators

The generator system shown in Figure 1-37 uses generators and regulators similar to those just discussed, except that the voltage regulator relay in the generator control has an extra coil wound on it through which paralleling current flows. This coil is connected between the regulator's P (paralleling) terminal and G (generator) terminal.

The paralleling relay unit contains two relays, whose coils are supplied with current from the G terminals of the two voltage regulators. This current

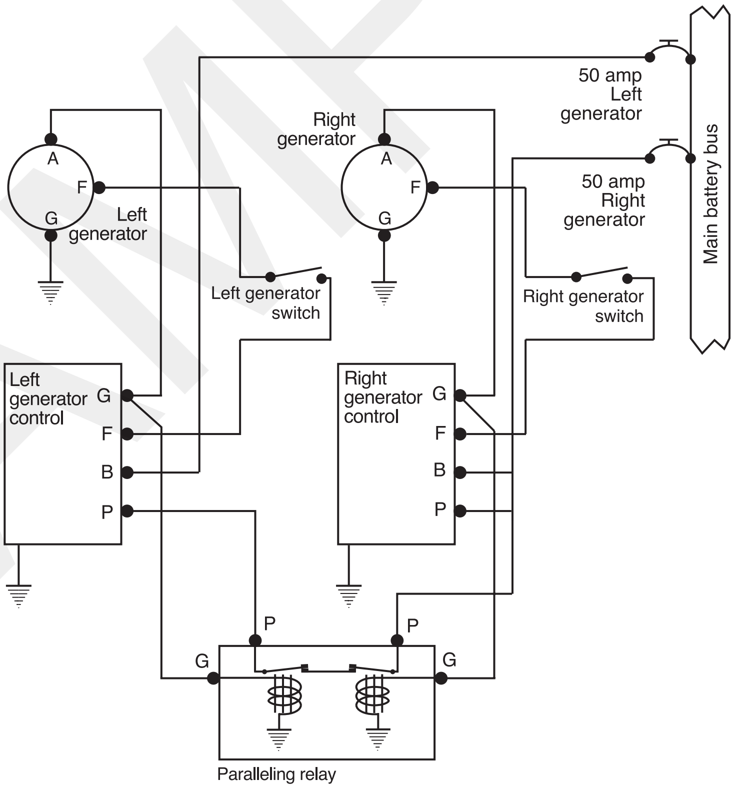


Figure 1-37. *Twin-engine aircraft generator system using vibrator-type voltage regulators and a paralleling relay.*

zero-center ammeter. An ammeter in a light aircraft electrical system located between the battery and the main bus. This ammeter shows the current flowing into or out of the battery.

vibrator-type voltage regulator. A type of voltage regulator used with a generator or alternator that intermittently places a resistance in the field circuit to control the voltage. A set of vibrating contacts puts the resistor in the circuit and takes it out several times a second.

paralleling circuit. A circuit in a multiengine aircraft electrical system that causes the generators or alternators to share the electrical load equally.

paralleling relay. A relay in a multiengine aircraft electrical system that controls a flow of control current which is used to keep the generators or alternators sharing the electrical load equally.

The relay opens automatically to shut off the flow of paralleling current any time the output of either alternator or generator drops to zero.

Another type of filter that is widely used for turbine engine fuel systems is the wafer screen filter seen in Figure 2-29. The filtering element is a stack of wafer-type screen disks made of a 200-mesh bronze, brass, or stainless steel wire screen. This type of filter can remove very tiny particles from the fuel and at the same time can withstand the high pressures found in a turbine engine fuel system.

Some of the fuel filters used in jet transport aircraft have a pressure switch across the filtering element. If ice should form on the filter and block the flow of fuel, the pressure drop across the filter will increase enough to close the contacts and turn on a light on the flight engineer's panel, warning that ice is forming on the filter.

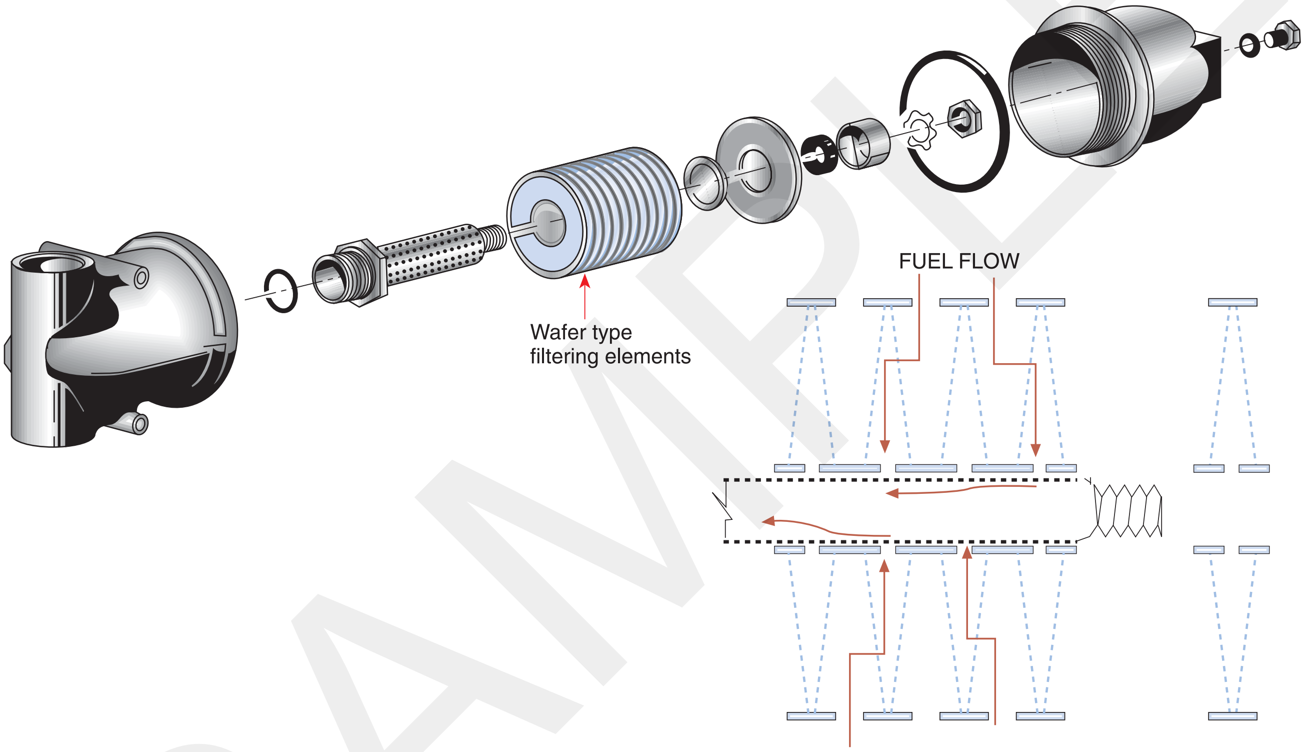


Figure 2-29. *A wafer-screen-type fuel filter.*

Stacked wafers on center shaft

Single wafer

STUDY QUESTIONS: FUEL FILTERS AND STRAINERS

Answers are provided on page 169.

55. It ____________ (is or is not) possible to get rid of all of the water in aviation fuel.

56. One problem with the water that condenses from turbine engine fuel is that it clogs the fuel screens when it ________________ .

57. Water can be prevented from freezing on the fuel screens by adding an ____________________ additive to the fuel.

58. Micro-organisms that form scum inside a fuel tank are killed by the ____________________ additive that is used in the fuel.

59. The main fuel strainers are located at the lowest point in the fuel system so it will trap and hold any _______________ in the system.

60. The fuel filters on some jet transport aircraft have a pressure switch across the filtering element. This switch will turn on a warning light on the flight engineer's panel if _____________ clogs the filter.

Fuel Valves

Aircraft fuel systems are complex and usually have several tanks, pumps, strainers and much plumbing. The valves that control the flow of fuel through these systems are vital components of the fuel system.

The valves must be capable of carrying all of the required fuel flow without an excessive pressure drop, and all valves must have some form of detent, a positive method of determining when they are in each marked position.

Plug-Type Valves

Some of the smaller aircraft use a simple plug-type selector valve in which a conical nylon or brass plug is rotated in a mating hole in the valve body. The plug is drilled in such a way that it can connect the outlet to any one of the inlets that is selected.

A spring-loaded pin anchored into the valve shaft slips into a detent when the cone is accurately aligned with the holes in the valve body. The pin slips into the detent notches in the washer when the two align. This detent allows the pilot to tell by feel when the valve is in its fully open or fully closed position. See Figure 2-30.

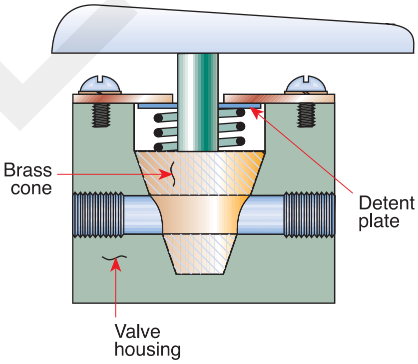


Figure 2-30. *Plug-type fuel selector or shutoff valve.*

detent. A spring-loaded pin or tab that enters a hole or groove when the device to which it is attached is in a certain position. Detents are used on a fuel valve to provide a positive means of identifying when the valve is in each of the selectable positions.

Poppet-Type Selector Valve

The poppet-type selector valve has many advantages over other types of hand-operated valves. It has a positive feel when any tank is in the full ON position and its design ensures that the line to a tank is either fully open or fully closed, with no possibility of an intermediate position.

Figure 2-31 shows a typical poppet-type selector valve. The handle rotates a cam which forces the poppet for the selected tank off its seat and fuel flows from that tank to the engine. Springs hold the poppets for all the other tanks tight against their seat. A spring-loaded indexing pin drops into a notch, or detent, in an indexing plate each time a poppet is fully off of its seat. It also drops into the notch when the valve in the OFF position and all of the poppets are seated.

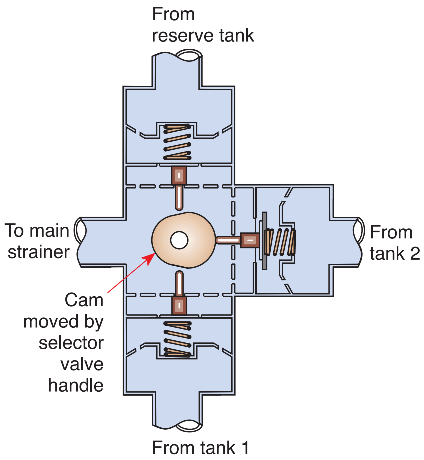


Figure 2-31. *A typical poppet-type fuel selector valve.*

Electric Motor-Operated Sliding Gate Valve

All large aircraft use electrically operated valves in their fuel systems. Common types of electrically operated valves are motor-driven gate valves and solenoid-operated poppet valves.

The valve in Figure 2-32 is a motor-driven gate valve. The geared output of a reversible electric motor drives a crank arm which moves the gate through a slot to cover the opening for the fuel line. Reversing the motor rotates the arm so it pulls the gate back and uncovers the fuel line opening. The gate is prevented from leaking by spring-loaded nylon seals, or O-rings that the gate slides between to cover the passage.

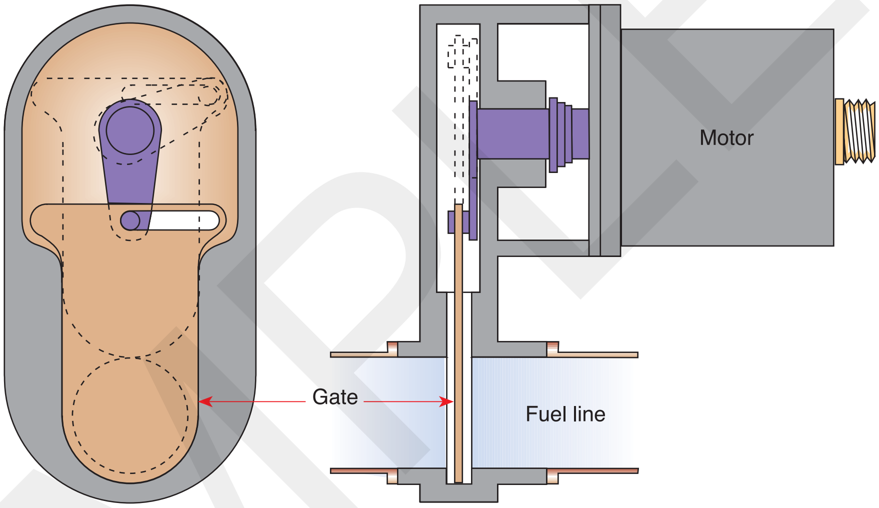


Figure 2-32. *Electric motor-operated sliding gate-type fuel valve.*

Solenoid-Operated Poppet-Type Fuel Shutoff Valve

The solenoid-operated poppet-type shutoff valve in Figure 2-33 uses a pulse of DC electricity in one circuit to open the valve and a pulse in another circuit to close it.

To open the valve, the opening solenoid is energized with a pulse of electricity. The magnetism produced by the pulse pulls the valve stem up until the spring behind the locking stem can force it into the notch in the valve stem. The locking stem holds the valve open.

To close the valve, the closing solenoid is energized with a pulse of electricity. The magnetism produced by this pulse pulls the locking stem back and allows the valve spring to close the valve.

Absolute Pressure Instruments

The most accurate device for measuring absolute pressure is the mercury barometer, a glass tube about 34 inches long and one inch in diameter closed at one end and filled with mercury. Its open end is immersed in a bowl of mercury. See Figure 4-1. The mercury drops down in the tube and leaves an empty space, or a vacuum, above it. The weight of the air pressing down on the mercury in the bowl holds the mercury up in the tube at a height proportional to the pressure of the air. Standard atmosphere at sea level holds the mercury up in the tube until the top of the column is 29.92 inches, or 760 millimeters, above the top of the mercury in the bowl.

A mercury barometer is not a convenient instrument to carry in an aircraft, so the aneroid (no liquid) barometer has been developed. This instrument uses a sealed, evacuated, concentrically corrugated metal capsule as its pressure-sensitive mechanism.

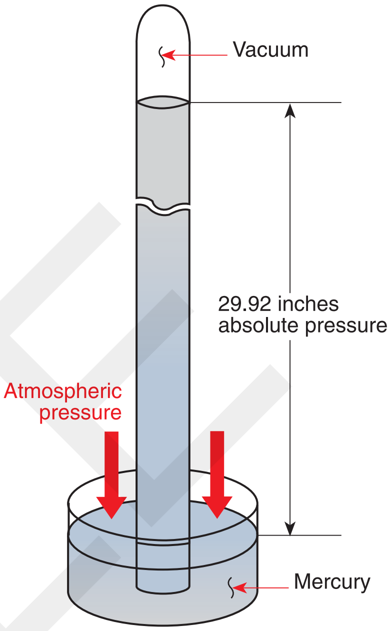


Figure 4-1. *A mercury barometer is the most accurate instrument to measure absolute pressure.*

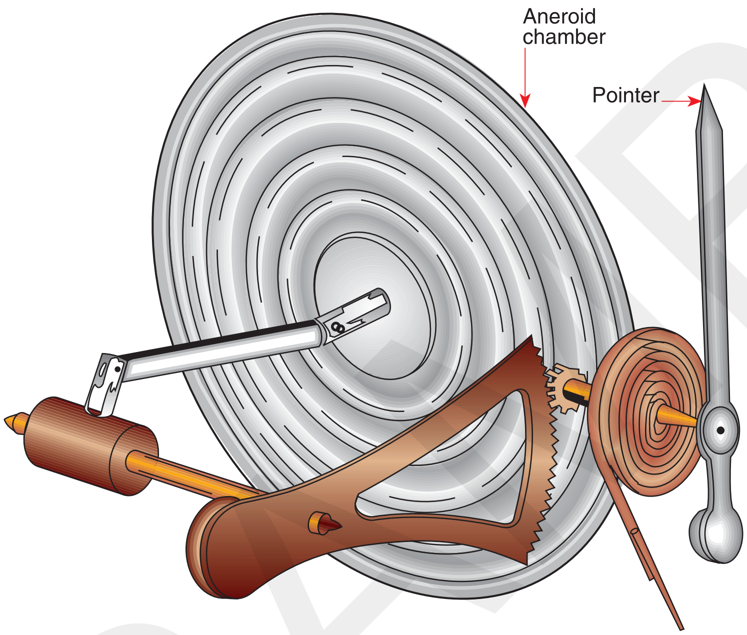


Figure 4-2. *An aneroid barometer mechanism.*

The concentric corrugations provide a degree of springiness that opposes the pressure of the air. See Figure 4-3. As the air pressure increases, the thickness of the capsule decreases, and as the pressure decreases, the capsule expands. A rocking shaft, sector gear, and pinion multiply the change in dimension of the capsule and drive a pointer across a calibrated dial.

aneroid. The sensitive component in an altimeter or barometer that measures the absolute pressure of the air. The aneroid is a sealed, flat capsule made of thin corrugated disks of metal soldered together and evacuated by pumping all of the air out of it. Evacuating the aneroid allows it to expand or collapse as the air pressure on the outside changes.

rocking shaft. A shaft used in the mechanism of a pressure-measuring instrument to change the direction of movement by 90° and to amplify the amount of movement.

sector gear. A part of a gear wheel that contains the hub and a portion of the rim with teeth.

pinion. A small gear that meshes with a larger gear, a sector of a gear, or a toothed rack.

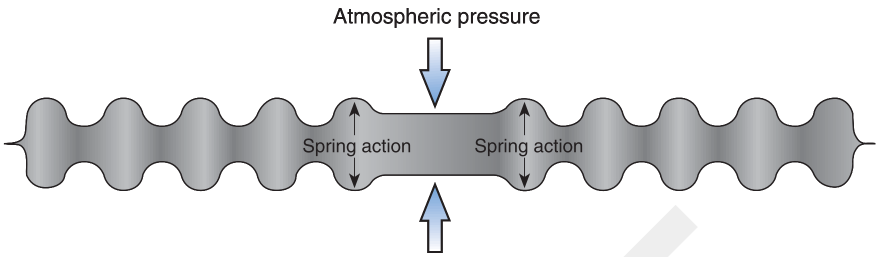


Figure 4-3. *The spring action of the corrugations opposes the pressure of the air to measure any changes in the air pressure.*

barometric scale. A small window in the dial of a sensitive altimeter in which the pilot sets the barometric pressure level from which the altitude shown on the altimeter is measured. This window is sometimes called the "Kollsman" window.

Absolute pressure is measured in an aircraft to determine altitude. The knob in the lower left-hand corner of the altimeter in Figure 4-4 adjusts the barometric scale in the window on the right side of the dial to set the pressure level from which the absolute pressure is referenced. The absolute pressure is expressed in feet of altitude from the referenced pressure level.

Figure 4-4. *An altimeter measures absolute pressure and displays it as feet of altitude above the pressure reference level that has been set into the barometric window.*

Gauge Pressure Instruments

gauge pressure. Pressure referenced from the existing atmospheric pressure.

Bourdon tube. A type of pressure-indicating mechanism used in most oil pressure and hydraulic pressure gauges. It consists of a sealed, curved tube with an elliptical cross section. Pressure inside the tube tries to straighten it, and as it straightens, it moves a pointer across a calibrated dial. Bourdon tube pressure gauges can be used to determine temperature when they measure the pressure of a sealed container of a volatile liquid, such as methyl chloride, whose pressure varies with its temperature.

Gauge pressure is measured from the existing barometric pressure and is actually the pressure that has been added to a fluid.

A Bourdon tube is typically used to measure gauge pressure. This tube is a flattened thin-wall bronze tube formed into a curve as in Figure 4-5. One end of the tube is sealed and attached through a linkage to a sector gear. The other end is connected to the instrument case through a fitting that allows the fluid to be measured to enter.

When the pressure of the fluid inside the tube increases, it tries to change the cross-sectional shape of the tube from flat to round. As the cross section changes, the curved tube tends to straighten out. This in turn moves the sector gear, which rotates the pinion gear on which the pointer is mounted.

Bourdon tube instruments measure relatively high pressures like those in engine lubricating systems and hydraulic systems. Lower pressures such as instrument air pressure, deicer air pressure, and suction are often measured with a bellows mechanism much like an aneroid capsule. Figure 4-6 shows this mechanism. The pressure to be measured is taken into the bellows. As the pressure increases, the bellows expands and its expansion rotates the rocking shaft and the sector gear. Movement of the sector gear rotates the pinion gear and the shaft on which the pointer is mounted.

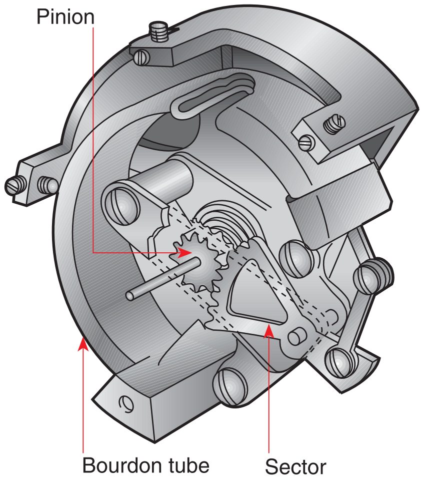


Figure 4-5. *A Bourdon tube mechanism is used to measure such gauge pressures as engine lubricating oil pressure and hydraulic fluid pressure.*

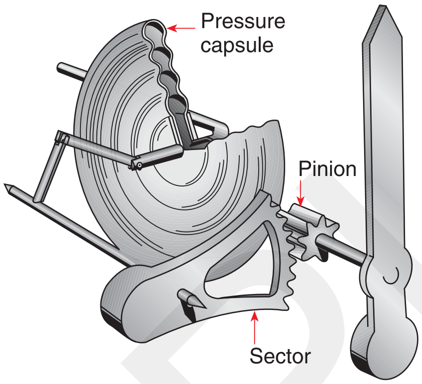


Figure 4-6. *A bellows mechanism is used to measure low gauge pressures.*

Differential Pressure Instruments

A differential pressure is simply the difference between two pressures. The indication on an airspeed indicator is caused by the difference between pitot, or ram, air pressure and static, or still, air pressure. Pitot pressure is taken into the inside of the diaphragm and static pressure is taken into the sealed instrument case. As the speed of the aircraft increases, the pitot pressure increases and the diaphragm expands, rotating the rocking shaft and driving the pointer across the dial.

differential pressure. The difference between two pressures. An airspeed indicator is a differential-pressure gauge. It measures the difference between static air pressure and pitot air pressure.

A differential bellows like that in Figure 4-8 on the next page is a popular instrument mechanism that can be used to measure absolute, differential, or gauge pressure.

When a differential bellows is used to measure absolute pressure, as it is when used in a manifold pressure gauge, one of the bellows is evacuated and sealed and the other bellows senses the pressure inside the engine intake manifold.

When used to measure differential pressure, as it is when used as a fuel pressure gauge, one bellows senses the air pressure at the carburetor inlet, and the other bellows senses the fuel pressure at the carburetor fuel inlet. A differential bellows can be used to measure gauge pressure by leaving one of the bellows open to the atmosphere and the other connected to the pressure to be measured.

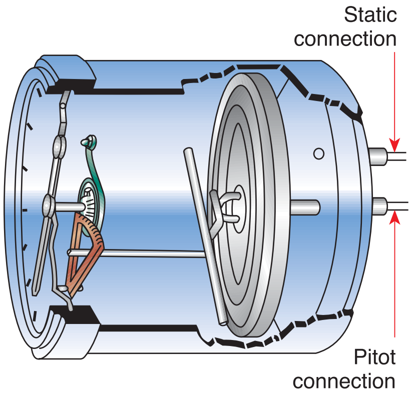


Figure 4-7. *An airspeed indicator is a differential pressure gauge which measures the difference between pitot, or ram air, pressure and static, or still air, pressure. The resulting differential pressure is displayed on the dial as knots, miles per hour, or kilometers per hour.*

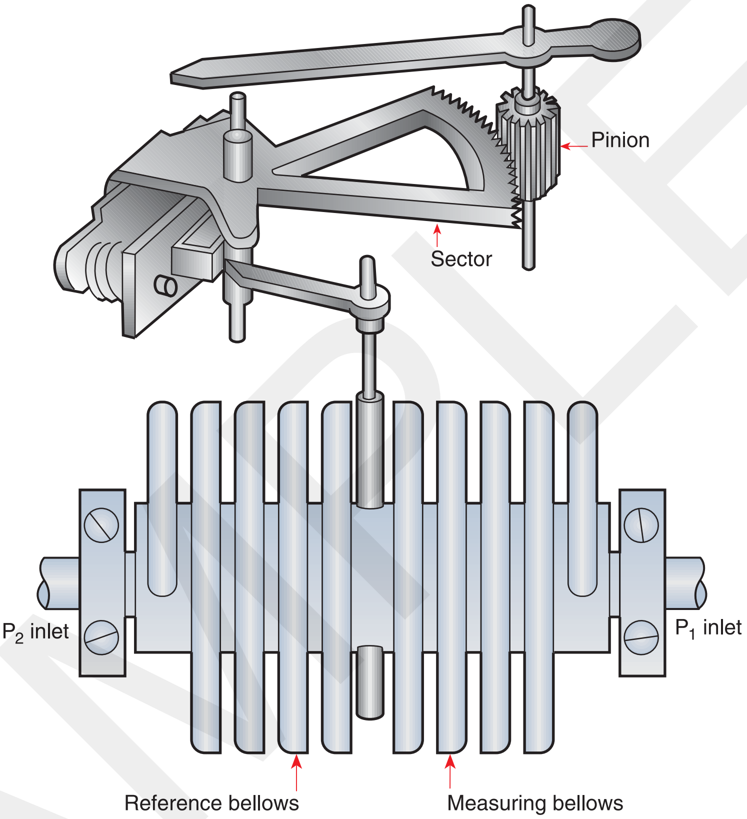


Figure 4-8. *Differential bellows mechanism that may be used to measure absolute, differential, or gauge pressure.*

airspeed indicator. A flight instrument that measures the pressure differential between the pitot, or ram, air pressure and the static pressure of the air surrounding the aircraft. This differential pressure is shown in units of miles per hour, knots, or kilometers per hour.

static air pressure. Pressure of the ambient air surrounding the aircraft. Static pressure does not take into consideration any air movement.

pitot pressure. Ram air pressure used to measure airspeed. The pitot tube faces directly into the air flowing around the aircraft. It stops the air and measures its pressure.

manifold pressure gauge. A pressure gauge that measures the absolute pressure inside the induction system of a reciprocating engine. When the engine is not operating, this instrument shows the existing atmospheric pressure.

Aircraft Instrument Systems

Knowing the basic operating principles of the various types of instruments will help understand the way these instruments relate to the entire aircraft. This section discusses the various systems in which specific instruments are installed.

Pitot-Static Systems

One of the most important instrument systems is the pitot-static system. This system serves as the source of the pressures needed for the altimeter, airspeed indicator, and vertical speed indicator.

A tube with an inside diameter of approximately ¼ inch is installed on the outside of an aircraft in such a way that it points directly into the relative airflow over the aircraft. This tube, called a pitot tube, picks up ram air pressure and directs it into the center hole in an airspeed indicator.

Small holes on either side of the fuselage or vertical fin or small holes in the pitot-static head sense the pressure of the still, or static, air. This pressure is taken into the case of the altimeter, airspeed indicator, and vertical speed indicator.

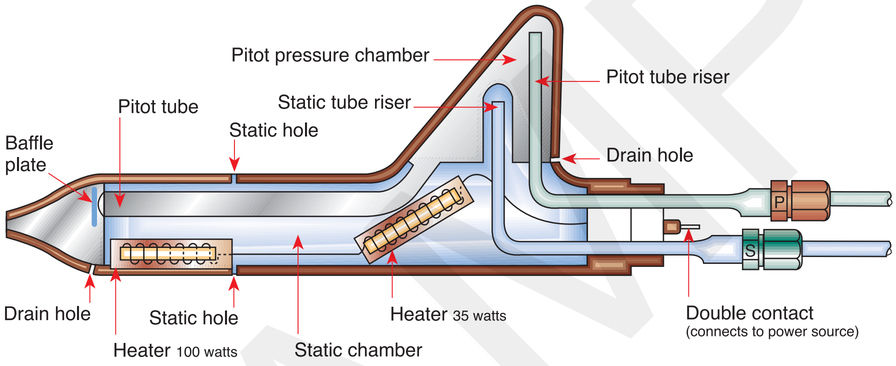


Figure 4-48. *An electrically heated pitot-static head.*

Figure 4-48 shows a typical pitot-static head. Ram, or impact, air is taken into the front of the head and directed up into the pitot pressure chamber. It is taken out of this chamber through the pitot-tube riser to prevent water from getting into the instrument lines. Any water that gets into the pitot head from flying through rain is drained overboard through drain holes in the bottom of the front of the head and in the back of the pressure chamber. Static air pressure is taken in through holes or slots in the bottom and sides of the head. An electrical heater in the head prevents ice from forming on the head and blocking either the static holes or pitot air inlet.

Pitot-static systems for light airplanes are similar to the one in Figure 4-49. The pitot tube for these aircraft is connected directly to the center opening of the airspeed indicator. The two flush static ports, one on either side of the fuselage, are connected together and supply pressure to the airspeed

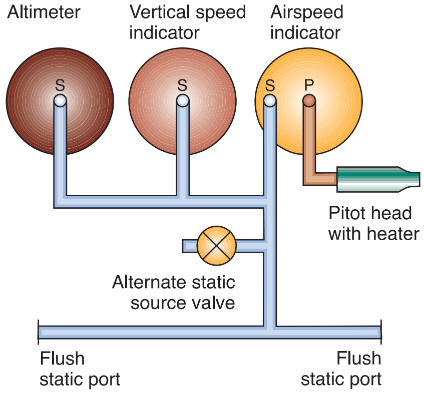


Figure 4-49. *A typical pitot-static system for a small general aviation airplane.*

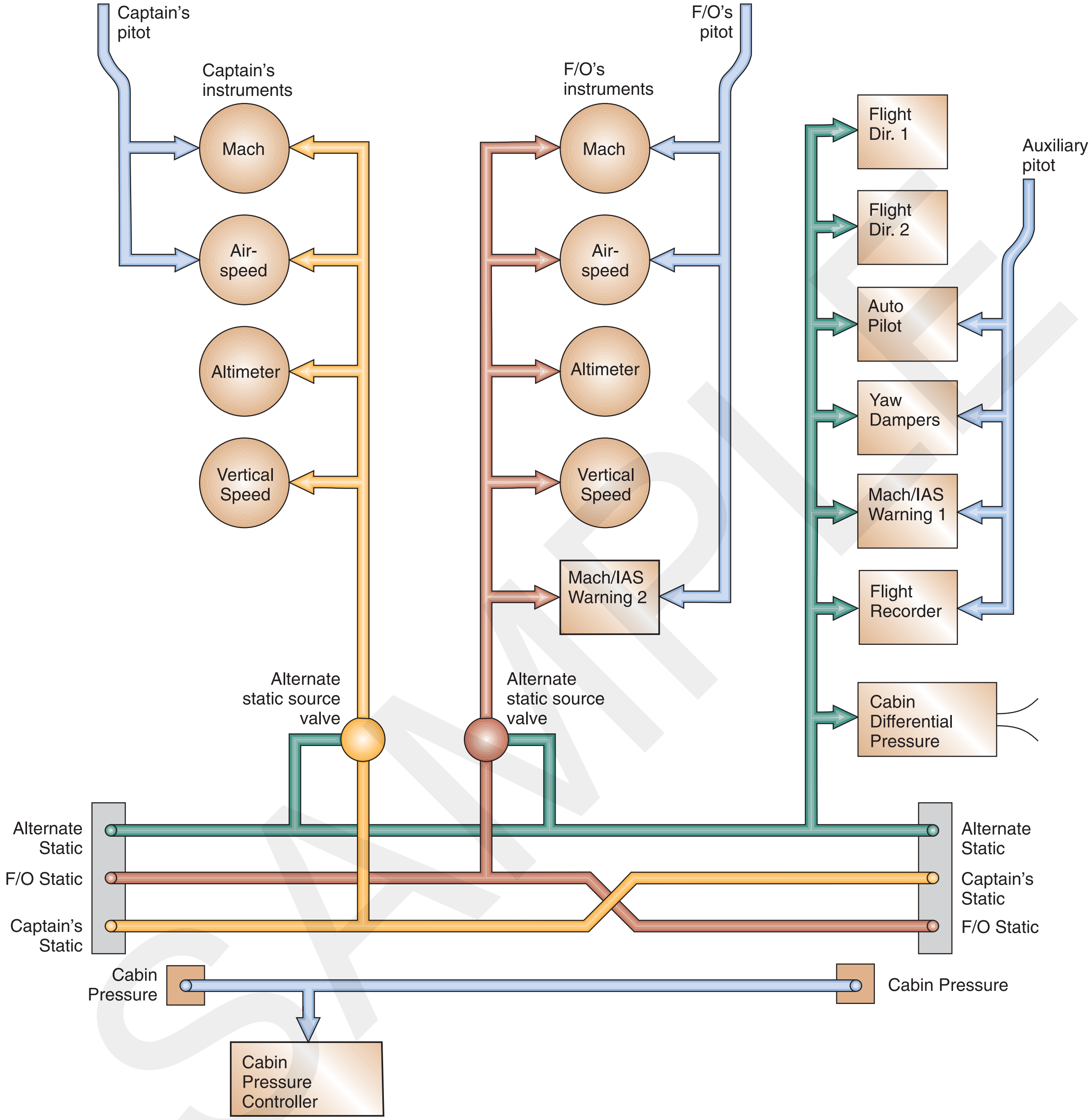


Figure 4-50. *Pitot-static system for a jet transport airplane.*

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