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Important Pitot Static System in Aircraft Control System

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ABSTRACT : In order to safely fly any aircraft, a pilot must understand how to interpret and operate the flight instruments. The pilot also needs to be able to recognize associated errors and malfunctions of these instruments. When a pilot understands how each instrument works and recognizes when an instrument is malfunctioning, he or she can safely utilize the instruments to their fullest potential. The pitot-static system is a combined system that utilizes the static air pressure, and the dynamic pressure due to the motion of the aircraft through the air. These combined pressures are utilized for the peration of the airspeed indicator (ASI), altimeter, and vertical speed indicator (VSI)

I. INTRODUCTION

Impact Pressure Chamber and Lines

The pitot tube is utilized to measure the total combined pressures that are present when an aircraft moves through the air. Static pressure, also known as ambient ressure, is always present whether an aircraft is moving or at rest. It is simply the barometric pressure in the local area. Dynamic pressure is present only when an aircraft is in motion; therefore, it can be thought of as a pressure due to motion. Wind also generates dynamic pressure. It does not matter if the aircraft is moving through still air at 70 knots or if the aircraft is facing a wind with a speed of 70 knots, the same dynamic pressure is generated.When the wind blows from an angle less than 90° off the nose of the aircraft, dynamic pressure can be depicted on the ASI. The wind moving across the airfoil at 20 knots is the same as the aircraft moving through calm air at 20 knots. The pitot tube captures the dynamic pressure, as well as the static pressure that is always present. The pitot tube has a small opening at the front which allows the total pressure to enter the pressure chamber. The total pressure is made up of dynamic pressure plus static pressure. In addition to the larger hole in the front of the pitot tube, there is a small hole in the back of the chamber which allows moisture to drain from the system should the aircraft enter precipitation. Both openings in the pitot tube need to be checked prior to flight to insure that neither is blocked. Many aircraft have pitot tube covers installed when they sit for extended periods of time. This helps to keep bugs and other objects from becoming lodged in the opening of the pitot tube.The one instrument that utilizes the pitot tube is the ASI. The total pressure is transmitted to the ASI from the pitot tube's pressure chamber via a small tube. The static pressure is also delivered to the opposite side of the ASI which serves to cancel out the two static pressures, thereby leaving the dynamic pressure to be indicated on the instrument. When the dynamic pressure changes, the ASI shows either increase or decrease, corresponding to the direction of change. The two remaining instruments (altimeter and VSI) utilize only the static pressure which is derived from the static port.Static

Pressure Chamber and Lines

The static chamber is vented through small holes to the free undisturbed air on the side(s) of the aircraft. As the atmospheric pressure changes, the pressure is able to move freely in and out of the instruments through the small lines which connect the instruments into the static system. An alternate static source is provided in some aircraft to provide static pressure should the primary static source become blocked. The alternate static source is normally found inside of the flight deck. Due to the venturi effect of the air flowing around the fuselage, the air pressure inside the flight deck is lower than the exterior pressure.

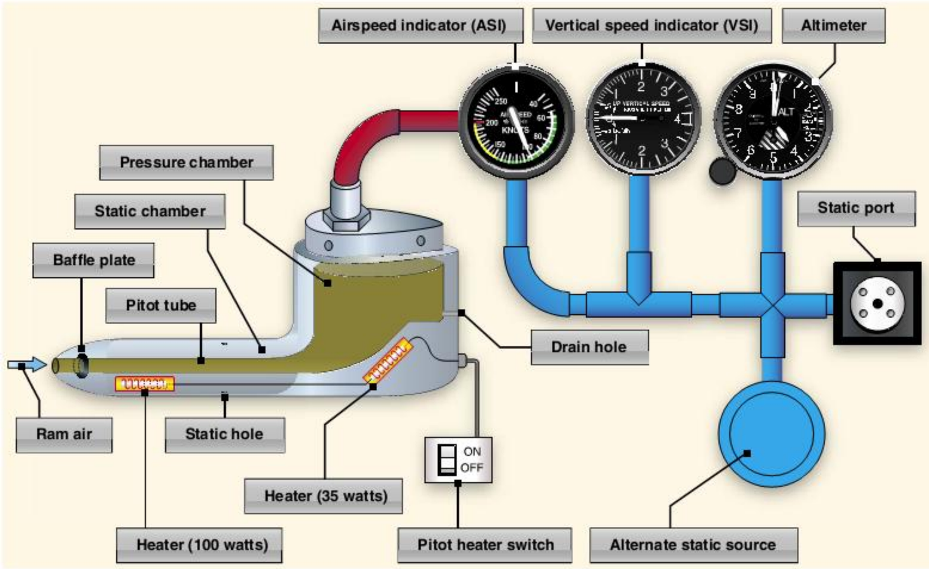

Figure 1. Pitot-static system and instruments

II. MATERIAL & METHODS

Altimeter

The altimeter is an instrument that measures the height of an aircraft above a given pressure level. Pressure levels are discussed later in detail. Since the altimeter is the only instrument that is capable of indicating altitude, this is one of the most vital instruments installed in the aircraft. To use the altimeter effectively, the pilot must understand the operation of the instrument, as well as the errors associated with the altimeter and how each effect the indication.A stack of sealed aneroid wafers comprise the main component of the altimeter. An aneroid wafer is a sealed wafer that is evacuated to an internal pressure of 29.92 inches of mercury (29.92 "Hg). These wafers are free to expand and contract with changes to the static pressure. A higher static pressure presses down on the wafers and causes them to collapse. A lower static pressure (less than 29.92 "Hg) allows the wafers to expand. A mechanical linkage connects the wafer movement to the needles on the indicator face, which translates compression of the wafers into a decrease in altitude and translates an expansion of the wafers into an increase in altitude.Notice how the static pressure is introduced into the rear of the sealed altimeter case. The altimeter's outer chamber is sealed, which allows the static pressure to surround the aneroid wafers. If the static pressure is higher than the pressure in the aneroid wafers (29.92 "Hg), then the wafers are compressed until the pressure inside the wafers is equal to the surrounding static pressure. Conversely, if the static pressure is less than the pressure inside of the wafers, the wafers are able to expand which increases the volume. The expansion and contraction of the wafers moves the mechanical linkage, which drives the needles on the face of the ASI.

Principle of Operation

The pressure altimeter is an aneroid barometer that measures the pressure of the atmosphere at the level where the altimeter is located, and presents an altitude indication in feet. The altimeter uses static pressure as its source of operation. Air is denser at sea level than aloft—as altitude increases, atmospheric pressure decreases. This difference in pressure at various levels causes the altimeter to indicate changes in altitude.The presentation of altitude varies considerably between different types of altimeters. Some have one pointer while others have two or more. Only the multipointer type is discussed in this handbook. The dial of a typical altimeter is graduated with numerals arranged clockwise from zero to nine. Movement of the aneroid element is transmitted through gears to the three hands that indicate altitude. The shortest hand indicates altitude in tens of thousands of feet, the intermediate hand in thousands of feet, and the longest hand in hundreds of feet.

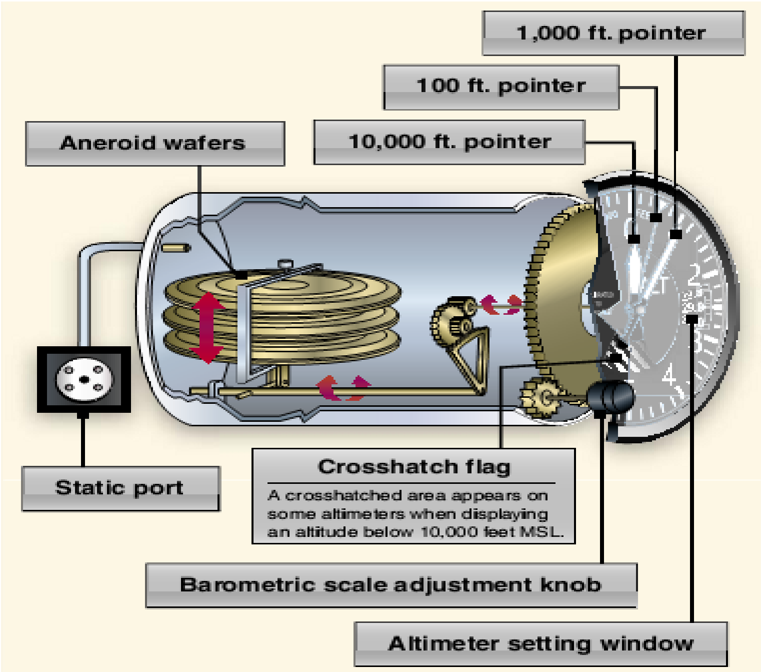

Figure 2. Altimeter

Vertical Speed Indicator (VSI)

The VSI, which is sometimes called a vertical velocity indicator (VVI), indicates whether the aircraft is climbing, descending, or in level flight. The rate of climb or descent is indicated in feet per minute (fpm). If properly calibrated, the VSI indicates zero in level flight.

Principle of Operation

Although the VSI operates solely from static pressure, it is a differential pressure instrument. It contains a diaphragm with connecting linkage and gearing to the indicator pointer inside an airtight case. The inside of the diaphragm is connected directly to the static line of the pitot-static system. The area outside the diaphragm, which is inside the instrument case, is also connected to the static line, but through a restricted orifice (calibrated leak).Both the diaphragm and the case receive air from the static line at existing atmospheric pressure. The diaphragm receives unrestricted air while the case receives the static pressure via the metered leak. When the aircraft is on the ground or in level flight, the pressures inside the diaphragm and the instrument case are equal and the pointer is at the zero indication. When the aircraft climbs or descends, the pressure inside the diaphragm changes immediately, but due to the metering action of the restricted passage, the case pressure remains higher or lower for a short time, causing the diaphragm to contract or expand. This causes a pressure differential that is indicated on the instrument needle as a climb or descent.

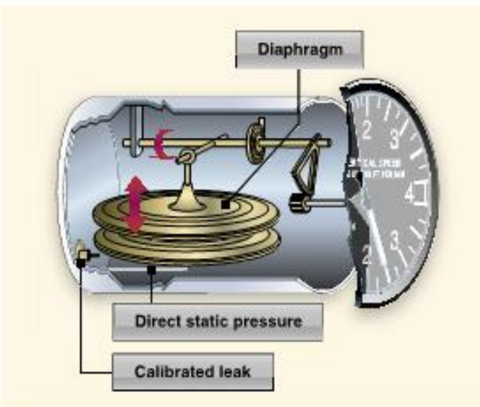

Figure 3. Vertical speed indicator (VSI)

Airspeed Indicator (ASI)

The ASI is a sensitive, differential pressure gauge which measures and promptly indicates the difference between pitot (impact/dynamic pressure) and static pressure. These two pressures are equal when the aircraft is parked on the ground in calm air. When the aircraft moves through the air, the pressure on the pitot line becomes greater than the pressure in the static lines. This difference in pressure is registered by the airspeed pointer on the face of the instrument, which is calibrated in miles per hour, knots (nautical miles per hour), or both. The ASI is the one instrument that utilizes both the pitot, as well as the static system. The ASI introduces the static pressure into the airspeed case while the pitot pressure (dynamic) is introduced into the diaphragm. The dynamic pressure expands or contracts one side of the diaphragm, which is attached to an indicating system. The system drives the mechanical linkage and the airspeed needle.Just as in altitudes, there are multiple types of airspeeds. Pilots need to be very familiar with each type.

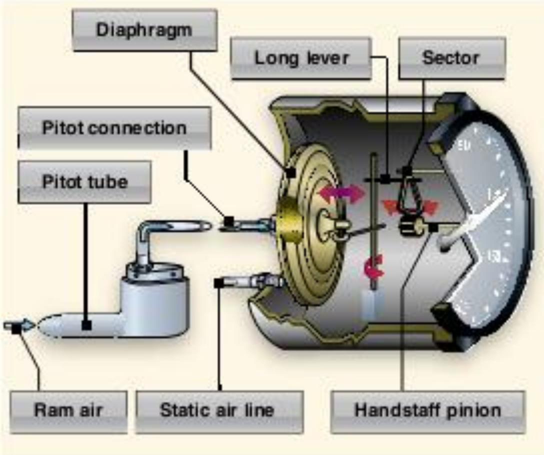

Figure 4. Airspeed indicator (ASI).

I. RESULT & DISCUSSION

Effect of Nonstandard Pressure and Temperature

It is easy to maintain a consistent height above ground if the barometric pressure and temperature remain constant, but this is rarely the case. The pressure temperature can change between takeoff and landing even on a local flight. If these changes are not taken into consideration, flight becomes dangerous.If altimeters could not be adjusted for nonstandard pressure, a hazardous situation could occur. For example, if an aircraft is flown from a high pressure area to a low pressure area without adjusting the altimeter, a constant altitude will be displayed, but the actual height of the aircraft above the ground would be lower then the indicated altitude. There is an old aviation axiom: “GOING FROM A HIGH TO A LOW, LOOK OUT BELOW.” Conversely, if an aircraft is flown from a low pressure area to a high pressure area without an adjustment of the altimeter, the actual altitude of the aircraft is higher than the indicated altitude. Once in flight, it is important to frequently obtain current altimeter settings en route to ensure terrain and obstruction clearance.Many altimeters do not have an accurate means of being adjusted for barometric pressures in excess of 31.00 inches of mercury ("Hg). When the altimeter cannot be set to the higher pressure setting, the aircraft actual altitude will be higher than the altimeter indicates. When low barometric pressure conditions occur (below 28.00), flight operations by aircraft unable to set the actual altimeter setting are not recommended. Adjustments to compensate for nonstandard pressure do not compensate for nonstandard emperature. Since cold air is denser than warm air, when operating in temperatures that are colder than standard, the altitude is lower than the altimeter indication. It is the magnitude of this “difference” that determines the magnitude of the error. It is the difference due to colder temperatures that concerns the pilot. When flying into a cooler air mass while maintaining a constant indicated altitude, true altitude is lower. If terrain or obstacle clearance is a factor in selecting a cruising altitude, particularly in mountainous terrain, remember to anticipate that a colder-than-standard temperature places the aircraft lower than the altimeter indicates. Therefore, a higher indicated altitude may be required to provide adequate terrain clearance. A variation of the memory aid used for pressure can be employed: “FROM HOT TO COLD, LOOK OUT BELOW.” When the air is warmer than standard, the aircraft is higher than the altimeter indicates. Altitude corrections for temperature can be computed on the navigation computer.

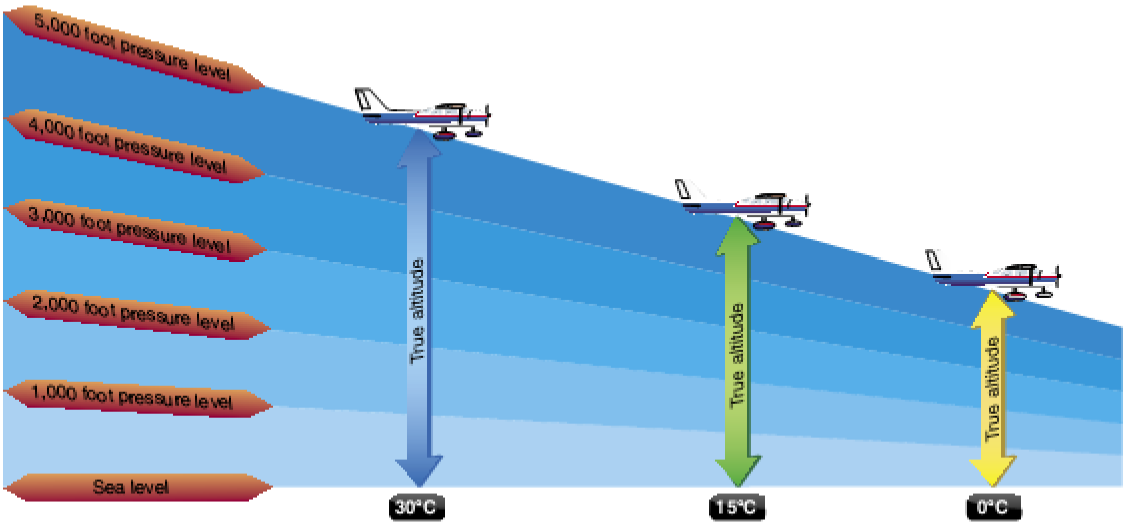

Figure 5. Effects of nonstandard temperature on an altimeter.

Blocked Pitot System

The pitot system can become blocked completely or only partially if the pitot tube drain hole remains open. If the pitot tube becomes blocked and its associated drain hole remains clear, ram air no longer is able to enter the pitot system. Air already in the system vents through the drain hole, and the remaining pressure drops to ambient (outside) air pressure. Under these circumstances, the ASI reading decreases to zero, because the ASI senses no difference between ram and static air pressure. The ASI no longer operates since dynamic pressure can not enter the pitot tube opening. Static pressure is able to equalize on both sides since the pitot drain hole is still open. The apparent loss of airspeed is not usually instantaneous but happens very quickly. If both the pitot tube opening and the drain hole should become clogged simultaneously, then the pressure in the pitot tube is trapped. No change is noted on the airspeed indication should the airspeed increase or decrease. If the static port is unblocked and the aircraft should change altitude, then a change is noted on the ASI. The change is not related to a change in airspeed but a change in static pressure. The total pressure in the pitot tube does not change due to the blockage; however, the static pressure will change.Because airspeed indications rely upon both static and dynamic pressure together, the blockage of either of these systems affects the ASI reading. Remember that the ASI has a diaphragm in which dynamic air pressure is entered. Behind this diaphragm is a reference pressure called static pressure that comes from the static ports. The diaphragm pressurizes against this static pressure and as a result changes the airspeed indication via levers and indicators

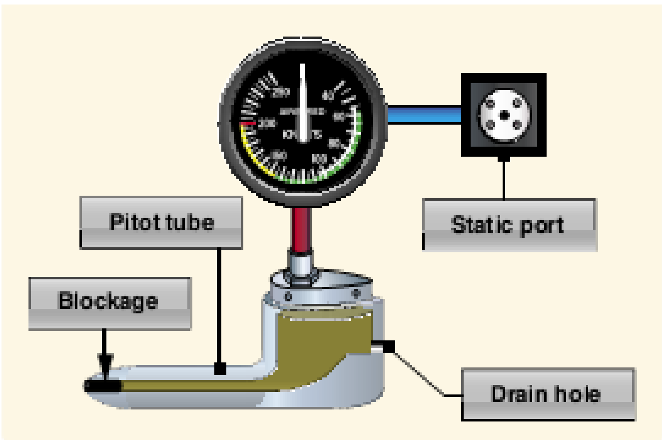

Figure 6. A blocked pitot tube, but clear drain hole

Blocked Static System

If the static system becomes blocked but the pitot tube remains clear, the ASI continues to operate; however, it is inaccurate. The airspeed indicates lower than the actual airspeed when the aircraft is operated above the altitude where the static ports became blocked, because the trapped static pressure is higher than normal for that altitude. When operating at a lower altitude, a faster than actual airspeed is displayed due to the relatively low static pressure trapped in the system. Revisiting the ratios that were used to explain a blocked pitot tube, the same principle applies for a blocked static port. If the aircraft descends, the static pressure increases on the pitot side showing an increase on the ASI. This assumes that the aircraft does not actually increase its speed. The increase in static pressure on the pitot side is equivalent to an increase in dynamic pressure since the pressure can not change on the static side. If an aircraft begins to climb after a static port becomes blocked, the airspeed begins to show a decrease as the aircraft continues to climb. This is due to the decrease in static pressure on the pitot side, while the pressure on the static side is held constant.A blockage of the static system also affects the altimeter and VSI. Trapped static pressure causes the altimeter to freeze at the altitude where the blockage occurred. In the case of the VSI, a blocked static system produces a continuous zero indication

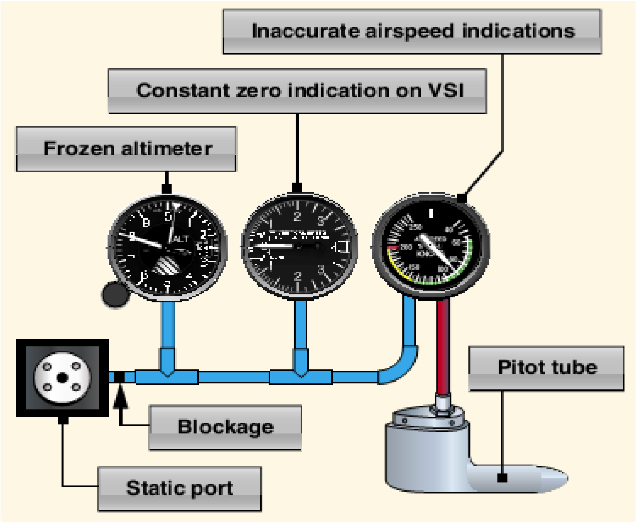

Figure 7. Blocked static system.

II. CONCLUSION

- As part of a preflight check, proper operation of the VSI must be established. Make sure the VSI indicates near zero prior to leaving the ramp area and again just before takeoff. If the VSI indicates anything other than zero, that indication can be referenced as the zero mark. Normally, if the needle is not exactly zero, it is only slightly above or below the zero line. After takeoff, the VSI should trend upward to indicate a positive rate of climb and then, once a stabilized climb is established, a rate of climb can be referenced.
- Instrument Check Prior to takeoff, the ASI should read zero. However, if there is a strong wind blowing directly into the pitot tube, the ASI may read higher than zero. When beginning the takeoff, make sure the airspeed is increasing at an appropriate rate.
- Blockage of the Pitot-Static SystemErrors almost always indicate blockage of the pitot tube, the static port(s), or both. Blockage may be caused by moisture (including ice), dirt, or even insects. ring preflight, make sure the pitot tube cover is removed. Then, check the pitot and static port openings. A blocked pitot tube affects the accuracy of the ASI, but, a blockage of the static port not only affects the ASI, but also causes errors in the altimeter and VSI.

III. SUMMARY

Flight instruments enable an aircraft to be operated with maximum performance and enhanced safety, especially when flying long distances. Manufacturers provide the necessary flight instruments, but to use them effectively, pilots need to understand how they operate. As a pilot, it is important to become very familiar with the operational aspects of the pitot-static system and associated instruments.

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