Pitot-Static Failures

Session Time: One, 50-minute session

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

A deep understanding of how an aircraft operates enables a pilot to fly the aircraft to its maximum capabilities in both normal and abnormal situations. (EU 5)

ESSENTIAL QUESTIONS

1. Can an airplane fly without its instruments?
2. What can cause instruments to fail?

LEARNING GOALS

Students Will Know

- The causes of pitot-static failures
- How to recognize a pitot-static failure
- Instrument indications in the case of a pitot-static failure
- Actions to take when confronted with pitot-static failure

Students Will Be Able To

- *Compare* the effects of pitot-static system blockages on flight instruments. (DOK-L3)
- *Analyze* instrument readings to determine whether the pitot and or static systems are blocked. (DOK-L4)
- *Predict* the effects of pitot-static blockages on different instruments. (DOK-L3)

ASSESSMENT EVIDENCE

Warm-up
Students watch a video involving a pitot-static failure and discuss possible causes and solutions of the failure.

Formative Assessment
Students draw and label a diagram of the pitot-static system and answer questions about the causes and results of pitot-static failures.

Summative Assessment
Students will answer a series of questions about the causes and indications of pitot-static failure, as well as procedures for coping with a failure.

LESSON PREPARATION

MATERIALS/RESOURCES

- Pitot-Static Failures Presentation
- Pitot-Static Failures Student Activity 1
- Pitot-Static Failures Teacher Notes 1

LESSON SUMMARY

Lesson 1: Altimeter and VSI
Lesson 2: Airspeed Indicator
Lesson 3: Pitot-Static Failures

This lesson explains possible pitot-static failures, how a pilot can identify them, and how a pilot should react to them. Students will warm up by viewing a news report on an Air France flight that crashed following a pitot-static failure, which will lead into a discussion about what causes pitot-static failures.

Students will then learn the primary cause of pitot-static failures (blockage) and the three primary ways this blockage can occur. They will then discuss what a pilot experiences when each type of failure occurs and how pitot-static failure affects instruments in the cockpit. Students will then discuss how a pilot can continue to fly the aircraft without reference to these instruments. Finally, students will apply this new knowledge to an example scenario and answer questions about what they have learned.

BACKGROUND

As discussed in the first two lessons of this unit, aircraft measure static and dynamic air pressure through the pitot-static system, which "powers" three important instruments: the altimeter, airspeed indicator, and vertical speed indicator.

Static pressure is most often sensed through a static port, or small hole on the side of the aircraft. Some aircraft have alternate or "backup" static ports inside the cockpit. The aircraft uses static pressure in all three instruments. The altimeter senses the static pressure and mechanically moves a needle to display altitude. The vertical speed indicator senses changes in static pressure to move a needle that indicates to the pilot whether the aircraft is climbing or descending (and how fast it is doing so) providing rate and trend information.

Dynamic pressure isn't directly measured. Rather, the aircraft senses total pressure (ram pressure) using a pitot tube, often an L-shaped tube under the wing. The airspeed indicator uses the difference between static and total pressure dynamic pressureto display airspeed. The airspeed indicator is the only one of the three instruments to use both a static port and a pitot tube.

All three instruments, located in the cockpit, rely on sensing air pressure outside the aircraft through air lines to the pitot tube and static port. Most pitot-static system failures happen when a blockage in those lines occurs, preventing the instruments from sensing the correct outside air pressure. Blockages may be caused by ice, bugs, debris, or even protective tape that was not removed after washing or painting the aircraft.

MISCONCEPTIONS

While the pitot-static system provides extremely important information to a pilot, an aircraft will not fall out of the sky simply because of a blockage or other pitot-static system failure. When the pilot recognizes a pitot-static system failure and reacts correctly, the aircraft is perfectly flyable even with the failure. On the other hand, mishaps occur when a pilot does not recognize a failure or does not act correctly when a failure occurs. In large, modern, complex aircraft, computers help detect pitot-static system failures and either make a correction automatically or warn the pilot that a fault has been discovered. In smaller aircraft, the pilot must use instrument indications to identify and respond to the failure.

DIFFERENTIATION

To support verbal reasoning and increase participation in the class discussion during the **EXTEND** section of the lesson plan, organize the class into groups for Think-Pair-Share instead of a whole group discussion.

LEARNING PLAN

ENGAGE

Teacher Material: Pitot-Static Failures Presentation

Slides 1-3: Introduce the topic and learning objectives of the lesson.

Slide 4: Conduct the **Warm-Up**.

Warm-Up

Watch the CBS News report on the 2009 Air France Flight 447 crash, then discuss briefly the causes of the accident and the faulty instrument indications the pilots received.

"Air France Flight 447's harrowing end" (Length 3:13)
http://video.link/w/gLDg

Possible Responses: The pitot tube was blocked, likely by ice, resulting in false airspeed readings to the cockpit.

EXPLORE

Teacher Material: Pitot-Static Failures Presentation

Slide 5: A pitot-static failure is most often caused by a blockage in part of the pitot-static system. For the pitot tube, this could be a partial blockage (just the ram air) or a total blockage (ram air and drain). The static port could also be blocked. Each of these three failures creates a different instrument indication and problem.

Questions

How might the pitot tube or static port become blocked?
Possible answers: A bug could enter the pitot tube and build a nest, or the plane could fly into the bug and impact the pitot tube. Ice could accumulate in flight on either the pitot tube or static port. The static port could have been sealed and inadvertently left covered. For example, when aircraft are painted or washed, the static ports are often taped over. If the tape is not removed, the static port will be blocked.

Bonus question: What can you do as a pilot to prevent some of these sources of blockage?
Possible answers: Use a pitot tube cover when the airplane is parked or stored. Use pitot heat to prevent icing during flight. Perform a thorough pre-flight inspection of the aircraft to confirm the pitot tube and static ports are not blocked.

Slide 6: A blockage of ram air to the pitot tube will cause the airspeed indicator to show zero airspeed. Since there is no ram air (total pressure), the pitot tube will only sense static pressure. The airspeed indication is a function of dynamic pressure, which is the difference between the ram or total pressure entering the pitot tube and the static pressure entering the static port. Since the pitot tube and static port will sense the same pressure, the airspeed indicator will display zero airspeed.

Because the pitot tube feeds only the airspeed indicator, all other instruments will continue to display correct values.

The image on this slide illustrates a partial blockage of the pitot tube, as well as the open line connecting the pitot tube to the airspeed indicator, and the open line to the static port. As a result, the airspeed shows zero airspeed.

Slide 7: A total blockage of the pitot tube will result in a constant pressure within the pitot (ram air) side of the system. Since the airspeed indicator is a function of the difference between the total pressure (ram air) and static pressure in the system, as the static system changes (with changes in altitude), the airspeed indicator will change. With a climb, the static pressure will decrease, which will increase the difference between the probe/static sides; the result will be an increase in indicated (not actual) airspeed. With a descent, the static pressure will increase. Since the probe pressure is constant, the differential will be less, resulting in a decrease in indicated airspeed.

Because the pitot tube feeds only the airspeed indicator, all other instruments will continue to display correct values.

The image on this slide illustrates a total blockage of the pitot tube (ram port and drain hole). As the airplane climbs, the indicated airspeed increases, and with a descent the indicated airspeed decreases, even if actual speed remains constant.

Slide 8: When the static port becomes blocked, the air in the static system becomes trapped. As a result, the air will remain at a constant pressurethe same pressure it was at when the port became clogged. The altimeter will freeze at the last pressure indication and will not change. Since there is no change in sensed altitude, the vertical speed indicator will indicate zero, and it will not change. The airspeed indicator will continue to operate, but it will provide inaccurate readings. When the aircraft climbs above the altitude where the blockage occurred, the airspeed will indicate lower-than-actual airspeed because the trapped air in the system is at a higher pressure than it should be for that altitude. When the aircraft descends below the altitude where the static port became blocked, the airspeed indicator will indicate higher-than-actual airspeed because the trapped air is at a lower-than-expected pressure for the new lower altitude.

The image on this slide illustrates a blockage of the static port connecting to all three instruments, as well as the open line to the pitot tube.

Slide 9: Complete the **Formative Assessment**.

Formative Assessment

On a piece of paper, have students work individually to draw their own version of the diagram on slide 9 and label each element. Then have them write down answers to each of the questions on the slide. Have students turn in their work before reviewing the answers as a class.

Possible responses: The three areas that can become blocked are the pitot tube ram port, the pitot tube drain hole, and the static pressure port. All three pitot-static instruments—the airspeed indicator, the vertical speed indicator, and the altimeter are affected by a blocked static port. A static blockage will cause the airspeed indicator to show a zero reading because the air in the static system is trapped and remains at a constant pressure despite changes in altitude.

[DOK-L2; *recall, explain*]

EXPLAIN

Teacher Material: Pitot-Static Failures Presentation

Slide 10: Pitot-static failures can be difficult to detect, especially in Instrument Meteorological Conditions (IMC)i.e., flying in the cloudswhen there are no outside visual references to verify what the airplane is actually doing. The best preparation is for pilots to understand their aircraft's performance. The first indication that something is wrong is usually a sensation that something doesn't "feel right." For example, if the pilot adds power and increases pitch, the pilot knows the airplane should climb. If the altimeter doesn't move under those conditions, a failure should be suspected.

Slide 11: Once the system is suspected of failing, other methods of airspeed and altitude control should be used. First, the pilot should fly using pitch and power settings. A given power setting (such as 2,400 RPMs) and pitch (such as 2 degrees nose up) will always result in a particular airspeed in a given airplane. For example, these settings in a Cessna 172 will typically result in level flight at just over 100 knots. Most pilots who are familiar with their aircraft know the pitch and power settings that will give a climb, level flight, or descent. In an emergency, they can use the settings to maintain control of the aircraft, even with failed flight instruments. Also, many airplanes now have GPS units that indicate ground speed and GPS altitude. These GPS indications are not exactly the same as those provided by the flight instruments, but they are good enough approximations in an emergency. Also, some aircraft have backup sources of static pressure, typically located inside the cabin (but not for ram pressure). Activating this backup system may restore some static indications. Finally, pitot heat should be used if equipped and pitot tube icing is suspected.

Questions

Can an airplane fly without its pitot-static instruments?
Possible answers: Absolutelyprovided the pilot can fly the aircraft without these instruments. Pilots must be trained to identify and react to these failures, and pilots must review these failures regularly. It's important for pilots to know their airplane, including pitch and power settings so they can safely fly in the event of a pitot-static failure.

EXTEND

Teacher Material: Pitot-Static Failures Presentation

Slide 12: Present students with the scenario presented in the slide. Conduct a whole class discussion to explore the answers.

Questions

On a beautiful, sunny day, you take off from your local airport, whose field elevation is 4,000 feet.

You level off above the traffic pattern, admire the trees below you, and head west toward the mountains, where you plan to meet your family in a few hours.

You see the instrument readings shown on the slide.

- What is wrong with your airplane?
- What should you do?

Possible answers: The scenario indicates you took off from an airport with an elevation of 4,000 feet. The instruments in the graphic indicate a current altitude of 4,000 feet. If your altimeter still

shows 4,000 feet as you're flying, then you likely have a blocked static port. This also means your airspeed is likely inaccurate and your vertical speed indicator will be stuck at zero (as indicated in the graphic). You can activate your alternate static source, if equipped, to give more accurate readings. However, even though you may want to continue your flight to visit your family, the most advisable course of action is to return to your home airport and have maintenance performed on the aircraft. If you do not have an alternate static source, you should use known pitch and power settings, with a GPS backup, if available.

EVALUATE

Teacher Materials: Pitot-Static Failures Presentation, Pitot-Static Failures Teacher Notes 1
Student Material: Pitot-Static Failures Student Activity 1

Slides 13-18: Quiz students on questions from the Private Pilot Knowledge Test.

Slide 19: Conduct the **Summative Assessment**.

Summative Assessment

Distribute copies of **Pitot-Static Failures Student Activity 1**. Working individually, have students complete the activity by answering the questions.

[DOK-L3; *assess, explain*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Student work shows:
    - Knowledge of the causes of pitot-static failures.
    - Ability to identify the indications of a pitot-static malfunction.
    - An understanding of how a pitot-static malfunction will affect different instruments.
    - An understanding of procedures to follow in the event of a pitot-static failure.
- Contributions show understanding of course of the concepts covered in the lesson.
- Contributions show in-depth thinking including analysis or synthesis of lesson objectives.

Points	Performance Levels
9-10	The student correctly answers the questions, showing excellent understanding of the causes of pitot-static failures, the indications of a failure in different instruments, the reasons for those indications, and the procedures to follow in the event of a failure.
7-8	The student correctly answers most of the questions, showing a good understanding of the causes of pitot-static failures, the indications of a failure, and the procedures to follow in the event of a failure. Student writing shows minor gaps in understanding.

5-6 The student understands the causes of pitot-static failures but does not recognize the indications of a failure and cannot explain how a pitot-static malfunction will affect different instruments. Student writing shows significant gaps in understanding.

0-4 The student is not able to identify the causes of a pitot-static failure, cannot, explain how instruments are affected or why, and cannot identify procedures to follow in the event of a failure. The student guesses or incorrectly explains sources of the problem showing little or no understanding of lesson content.

STANDARDS ALIGNMENT

NGSS STANDARDS

- **HS-ETS1-4** - Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
    - Science and Engineering Practices
        - Using Mathematics and Computational Thinking
    - Disciplinary Core Ideas
        - ETS1.B: Developing Possible Solutions
    - Crosscutting Concepts
        - Systems and System Models

COMMON CORE STATE STANDARDS

- **WHST.9-10.2** - Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
- **WHST.9-10.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.

REFERENCES

Pilot's Handbook of Aeronautical Knowledge: 8-10 through 8-11
2009 Air France Flight 447 crash CBS News Link: http://video.link/w/gLDg