Fuel Systems

Session Time: Four, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

The intended purpose and use of an aircraft drives aircraft design considerations and construction techniques, materials, and components. (EU1)

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. (EU5)

ESSENTIAL QUESTIONS

1. Why do pilots need to know more about their vehicle's fuel system than drivers do?
2. What happens to an airplane when it has contaminated fuel?
3. How can I safely refuel an airplane?

LEARNING GOALS

Students Will Know

- The components of aircraft fuel systems
- Various fuels used by aircraft
- Procedures for refueling an aircraft
- How to identify potential fuel related problems
- Strategies for preventing fuel contamination, fuel icing, fuel starvation, or other related issues

Students Will Be Able To

- *Analyze* accidents involving fuel systems and assess possible causes. (DOK-L4, L3)
- *Explain* the difference between fuels and identify which categories of aircraft in which they are commonly used. (DOK-L1, L3)
- *Apprise* other students of critical components of an aircraft fuel system. (DOK-L3)
- *Describe* guidelines for how to fuel an airplane safely. (DOK-L1)

ASSESSMENT EVIDENCE

Warm-up
Show students a humorous general aviation public safety announcement created by AOPA's Air Safety Institute. Lead a class discussion with questions that prompt thinking about the importance of fuel management and knowing how an airplane fuel system operates.

Formative Assessment
Assessment 1: In small groups, students will research one of the fuel system components discussed in the lesson. Students will determine how to teach the material to the rest of the class during a two-minute presentation.

Assessment 2: Assign each group of students a different type of fuel related accident (fuel starvation, fuel exhaustion, fuel contamination, or misfueling). Using the National Transportation Safety Board (NTSB) accident database, each group of students will select one accident and review the NTSB findings. The group will create a presentation that includes information about circumstances surrounding the accident, the role of fuel in the accident, additional causes of /contributors to the accident, and ideas for how the accident might have been prevented.

Summative Assessment
Students will review a preflight checklist and identify the items related to fuel and fuel systems. For each checklist item, students will describe why a pilot should perform this check. In addition, students will describe the differences between avgas and jet fuel and they will also describe three guidelines that pilots should follow in order to safely fuel an airplane.

LESSON PREPARATION

MATERIALS/RESOURCES

- Fuel Systems Presentation
- Fuel Systems Student Activity
- Fuel Systems Teacher Notes

Recommended Student Reading

- **Pilot's Handbook of Aeronautical Knowledge**
  Chapter Seven, Section on Fuel Systems
  https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/09_phak_ch7.pdf

LESSON SUMMARY

Lesson 1 - Fuel Systems
Lesson 2 - Electrical Systems
Lesson 3 - Hydraulics and Landing Gear

The lesson begins with a warm-up in which students watch a short, humorous video and have a brief class discussion to get them thinking about the significance of fuel management and the importance of understanding the fuel system. Students will go on to explore the purpose, design and components of aircraft fuel systems. They will begin by learning the differences between gravity-fed and fuel-pump-driven fuel systems, as well as the special case of inverted fuel systems used for aircraft that perform extensive aerobatic maneuvers and fly upside down.

In the next part of the lesson, students will learn about the purpose and use of key components of aircraft fuel systems, including fuel tanks, pumps, primers, filler systems, gauges, fuel selectors, strainers, sumps, and drains. In the first formative assessment, students pretend to be flight instructors and work in small groups to develop a short "lesson" to creatively explain one or more of these components to a flight student.

Students go on to examine the types of fuel commonly used in aircraft, including jet fuel and avgas, before looking at the fueling process, including safety considerations and fueling guidelines. Working in small groups, they will research one of four types of fuel-related accidents—misfueling, fuel starvation, fuel exhaustion, and fuel contamination. Looking at accident reports from the National Transportation Safety Board, they will develop a presentation about the causes of the accident and how it might have been prevented. To complete the summative assessment, students will review a preflight checklist and identify the items related to fuel and fuel systems. For each checklist item, students will describe why a pilot should perform this check. In addition, students will describe the differences between avgas and jet fuel and they will also describe three guidelines that pilots should follow in order to safely fuel an airplane.

BACKGROUND

Engines require fuel to operate, and fuel systems are the means of delivering it. The fuel system's role is to store and transport fuel. In a previous lesson, students learned in detail about carburetors and fuel injection systems which ensure there is fuel in the cylinders at the right moment for combustion. These components could be considered the end point of the fuel system. In this lesson, students will learn about the many components that enable fuel to reach the carburetor or fuel injectors.

If you pull up to your local gas station, you'll typically find three grades of unleaded gasoline—regular with an octane rating of about 87, mid-grade with an octane rating of about 89, and premium with an octane rating of about 93. While some manufacturers recommend one of these fuel grades over the others, the truth is that the vast majority of car engines will run quite effectively on any of these three grades. This is not the case with aircraft engines. Although a few can operate on more than one grade of fuel, most have strict requirements about the fuel used and can only be operated safely on that fuel type or grade.

To help pilots and line personnel ensure that the right type of fuel is going in the right type of engine, aircraft fuels are color coded and there are placards on the aircraft stating the type of fuel required as well as special fueling nozzles to help minimize the chance of putting the wrong type of fuel in an airplane. In addition, pilots are required to visually examine fuel samples from each of their aircraft's fuel tanks before every flight to check for contamination and ensure they have the right type of fuel. Nevertheless, misfueling accidents do happen and the results are often tragic.

The fueling process itself requires additional precautions to ensure safety. In a car, you simply pull up to the pump, open the filler cap, and begin filling the tank. In an airplane, you must first ground the aircraft to the fueling source to prevent potentially explosive static discharge.

Finally, fuel management is very different in an airplane than it is in a car. Many more factors, including wind and altitude, affect how much fuel an aircraft uses to travel a given distance. And while most modern car fuel gauges are reasonably reliable, FAA regulations require that aircraft fuel gauges provide accurate readings only when the tank is empty. That's one reason why pilots must actually look inside each fuel tank before a flight to gauge how much fuel the aircraft actually contains.

MISCONCEPTIONS

Students may believe that managing the fuel in an airplane is as easy as managing the fuel in a car. In reality, airplane fuel management requires much greater systems knowledge, because the consequences of losing an engine in an airplane are much greater than losing an engine in a car. Pilots must think not only about running out of fuel, but they must also think about fuel starvation (when usable fuel is prevented from reaching the engine), misfueling with an inappropriate type or grade of fuel, contamination by water or particulate matter, and mistakes in the use of carburetor heat, boost pumps, or other system components.

Based on their experience with cars, students may also believe that aircraft engines can use different grades of fuel interchangeably. In aircraft, which have very specific performance requirements, that is typically not the case and only one grade of fuel will allow the engine to operate safely.

DIFFERENTIATION

To help students who may struggle to identify and focus on key learning points, divide the lesson into segments—components, fuel types, and fueling guidelines. Following each segment, ask students to write down the three most important ideas presented in that part of the lesson. Have students discuss their responses with a partner or in small groups.

LEARNING PLAN

ENGAGE

Teacher Material: Fuel Systems Presentation

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

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

Warm-Up

Show students a humorous general aviation public safety announcement created by AOPA's Air Safety Institute. This video serves as a good reminder about the importance of fuel management and knowing how an airplane fuel system operates. After the video, ask students two questions during a class discussion.

- "Would You Fly This Airline?" (Length 1:00)
  https://video.link/w/P40h

[DOK 2; *infer*]

Questions

How is fuel management in an airplane different from fuel management in a car?
If a driver runs out of fuel in their car, the engine will quit. When this happens, they can simply pull off the side of the road and call a parent or a tow company for help. In an airplane, running out of fuel also means the engine will quit, but with much greater consequence. Running out of fuel in the air oftentimes leads to an off-field, emergency landing. Pilots must not only worry about the consequences of running out of fuel, but they must also think about fuel starvation (usable fuel is prevented from reaching the engine), misfueling with an inappropriate type or grade of fuel, contamination by water or particulate matter, and mistakes in the use of carburetor heat, boost pumps, or other system components.

Why is it important to know how your airplane fuel system works?
Pilots have made forced landings with fuel still available in their tanks because they did not understand the system or how to operate it properly. Many pilots have also run out of fuel before safely reaching their destination. Ensuring the correct kind of fuel is in the tanks, knowing how to properly determine how much fuel is available, knowing how to feed the fuel to the engines, and how much fuel is being burned are all very important skills that a pilot must have.

EXPLORE

Teacher Material: Fuel Systems Presentation

Slide 5: The purpose of the fuel system is to store and deliver fuel to the engine. Fuel systems must be carefully designed and maintained to ensure that they can function reliably under all operating conditions. The functionality of the fuel system may be impaired by using the wrong grade or type of fuel, fuel contamination, or operating in unusual attitudes (such as performing aerobatic maneuvers).

Fuel systems can be divided into two main types—gravity fed or fuel pump operated. Each of these will be covered in greater detail in upcoming slides.

Slide 6: Gravity fed fuel systems depend on gravity to deliver fuel to the engine. They constitute the simplest form of fuel system, making them reliable and affordable. This type of system is common in high-wing aircraft, where the fuel is stored in wing tanks located above the engine. Gravity draws fuel from the tanks into the engine. The pilot can typically choose whether to draw from the left tank, right tank, or both tanks.

Slide 7: Pump driven fuel system typically have two pumps—a main pump and an auxiliary or boost pump. The main pump is usually located near the engine and is mechanically driven by the engine. The boost pump may be located elsewhere in the aircraft and is typically electrically driven. Depending on the system design, the boost pump may provide fuel pressure for starting the engine, and may be required for takeoff, landing, or high-altitude flight. The boost pump is controlled by a switch in the cockpit.

Slide 8: Aircraft that fly upside down pose a special challenge when it comes to delivering fuel to the engine. These aircraft have special inverted fuel systems (and oil systems, too). Most inverted fuel systems use either a “flop tube” or a “header tank” to ensure fuel continues to flow to the engine, even when the aircraft is upside down. A flop tube is a flexible tube with a weight on one end that’s located inside the fuel tank. Fuel is drawn from the weighted end of the tube, which is always at the lower side of the tank. When the aircraft turns upside down, the fuel “flops” to what was the top of the tank and so does the weighted end of the tube. When the aircraft turns upright, the fuel and the tube flop again. A header tank is a small fuel tank located low down in the cockpit or fuselage. When the aircraft is upside down, the header tank is above the engine, allowing gravity to pull fuel from the tank into the engine.

Slide 9: In a class discussion, ask students to name as many components of an aircraft fuel system as they can. They should draw from their knowledge of automobile fuel systems and what they’ve learned so far during this course. Make a list of their ideas on the board. The next slide will list the most prominent components.

Slide 10: The fuel system includes all components needed to store fuel and deliver it to the engine for combustion. The design of the fuel system determines the components needed, but they typically include:

- Fuel tanks
- Filler system
- Pumps
- Primer
- Gauges
- Selector
- Strainers
- Sumps
- Drains

These components will be addressed in upcoming slides. Students learned about additional elements of the system, including carburetors and fuel injection systems in an earlier lesson.

This will conclude the first session of this lesson.

EXPLAIN

Teacher Material: **Fuel Systems Presentation**

Slide 11: Primers are used in both gravity fed and pump systems. A locking knob in the cockpit vaporizes fuel and pushes it directly into the cylinders. This makes fuel available for engine start. The primer can be especially helpful in cold weather when there may not be enough heat to vaporize fuel in the carburetor until the engine warms up. But overpriming can flood the engine, creating a mixture that is too rich to ignite properly, making the engine harder to start. Primer knobs generally lock in the closed position, and should be kept in the locked position during flight. Otherwise vibrations may move the knob, sending additional fuel into the cylinders and creating an over-rich condition that could cause the engine to run rough.

Slide 12: In most aircraft, the fuel tanks are located inside the wings. But there are special situations where temporary or permanent tanks may be added to provide additional fuel and increase the range of the aircraft. Tip tanks, like the one shown in the photo on the slide, are permanently attached to the outboard end of each wing. On some aircraft, external tanks may also be added. These can typically be removed when they are not needed, and can be replaced when the mission calls for extra range or endurance. Sometimes small aircraft need to be flown long distances, such as when moving a light aircraft from Europe to the United States. In cases like this, ferry tanks may be added to provide the needed fuel for flying over the ocean. Ferry tanks are often installed inside the passenger compartment and are removed following the ferry flight. Weight and balance must be taken into consideration any time supplemental fuel tanks are added or removed.

Slide 13: Fuel filler openings provide a means of filling the tanks with fuel. They are typically located on top of each wing. For high-wing aircraft and larger aircraft, a ladder may be needed to reach the fuel filler. The filler is covered with a cap, which may lock. Because the fillers are on top of the wings where they are exposed to weather and debris, the filler caps are especially important to prevent fuel contamination. Many fuel filler caps also have vents, which must be unobstructed.

Slide 14: Aircraft fuel tanks must be vented to the outside in order to ensure that the pressure is the same inside and outside the tanks. As an aircraft changes altitude throughout a flight, the air pressure can vary significantly. Ensuring that the pressure in the tanks changes with the pressure of the atmosphere prevents damage to the tanks and keeps the fuel flowing. Some aircraft have vents built into the fuel filler caps. More often, tanks are vented through a small, bent tube below each wing. These vent tubes often serve double duty as fuel overflow tubes. In hot weather, fuel in the tanks can expand. The overflow drain allows excess fuel to drain from the tank, preventing damage.

Slide 15: Aircraft fuel tanks come in a variety of materials and designs. Bladder tanks, which are common in light general aviation aircraft, are located in the wings. They look like large bags and are typically made with a heavy rubberized material. They can be removed for replacement. Rigid tanks have a rigid structure. The may be made of metal, plastic, or composite material such as fiberglass. Like bladder tanks they can be removed for replacement or maintenance. Wet wings are wings with sealed compartments to hold fuel. Because the fuel tanks are an integral part of the wings, they cannot be removed. This type of tank is common on larger aircraft.

Slide 16: Most aircraft have a fuel quantity gauge for each tank. In newer aircraft, they are part of a single instrument located in the cockpit. However, in some older aircraft there is a separate fuel gauge located just above each door, approximately where each wing connects to the fuselage. Fuel is typically measured in gallons in smaller aircraft but may be measured in pounds in larger aircraft. It's important for pilots to know that FAA regulations only require the fuel gauges to provide an accurate reading when the tank is *empty.* This is one more reason pilots *must* visually check the fuel supply in the tanks before every flight. It's also why careful fuel planning is vital, especially when traveling away from the airport. Some aircraft equipped with fuel pumps may also have a fuel pressure gauge. And some aircraft have a fuel flow gauge to help the pilot judge how much fuel is being consumed at any given time.

Slide 17: In aircraft with multiple fuel tanks, the fuel selector allows the pilot to choose the source of fuel being fed to the engine. A common type of fuel selector is a lever with four settings labeled Left, Right, Off, and Both. When the selector is set to Both, fuel is drawn from both wing tanks. This is often the required setting for takeoff and landing, and placards either on the fuel selector itself or located nearby provide information about requirements. Using the Both setting is no guarantee that fuel will be used from both tanks at equal rates. Many factors can cause one tank to use fuel faster than the other, including aircraft attitude and minor variations in the tanks themselves. This is one reason many aircraft give pilots the option to fly using just one tank to feed the engine. When the selector is set to left or right, only fuel from that tank will flow to the engine. This is helpful for balancing the fuel load during the course of a flight. In some aircraft, there is no Both setting. In this type of aircraft, or any time the pilot is flying from just one tank, it's important to switch tanks often both the maintain a balanced load and to prevent running a tank dry. Setting a timer as a reminder to switch tanks is good practice.

Slide 18: Keep in mind that the *only* time the FAA regulations require an aircraft fuel gauge to provide an accurate reading is when the tank is *empty.* It's important never to run a fuel tank dry. When the tank is empty, air may be able to enter the tank, causing vapor lock. (Vapor lock is defined as an interruption in the delivery of liquid fuel to the engine. Often, this is caused by excessive temperatures that cause the fuel to vaporize before it reaches the engine, but it can also be caused when air replaces liquid fuel in the system.) When liquid fuel is not being delivered to the fuel pump and /or carburetor, it cannot be pushed into the engine. Lack of fuel will cause the engine to stop, and it may be difficult or impossible to restart. Restarting a fuel-injected engine is especially difficult because the fuel can become so hot that it vaporizes in the fuel line, never reaching the engine.

Slide 19: Fuel strainers help reduce the amount of contaminants reaching the engine. A fuel strainer typically includes a small container into which fuel is fed from the fuel tank. Inside the container, the fuel is pushed through a screen or filter, before it is drawn into the carburetor or fuel injection system. The fuel strainer helps remove dirt, debris, and even moisture from the fuel.

Slide 20: A fuel sump is a low point in the fuel tank, typically located under each wing and sometimes under the belly of the aircraft as well. A Cessna 172S model, for example, has 13 different fuel sumps located in the wings and belly. Because most common contaminants, including water, are heavier than fuel, they sink into the sump where they can be drained. Pilots must drain a small amount of fuel from each sump before every flight. They are looking for signs of contamination such as water, dirt, or other debris. They are also checking to see that the fuel is of the correct grade—something they can determine from its color. Pilots must continue sumping each drain until there is no sign of contamination.

Slide 21: Contaminants can come from many sources. They may be pumped into the fuel tanks, or they may come from the tanks themselves. The most common type of contaminant is water. It is not uncommon for water to leak into the tanks through the filler cap. Aging or damaged seals around the filler may allow rain, snow, or ice to leak into the tanks. When tanks are left partially filled, condensation from trapped air may contaminate the fuel. Water is of particular concern because it can easily stop an engine. It may freeze in the cold temperatures common at higher altitudes, causing what's called "fuel system icing." The frozen water may block fuel lines, preventing fuel from reaching the engine, or it may make its way through the system and be ingested by the engine. Even if the water doesn't freeze, it can displace fuel in the carburetor, leaving the engine with no fuel to burn.

Slide 22: Complete the **Formative Assessment**. This will complete the second session of the lesson. It is likely that some groups may be teaching their "lesson" at the beginning of the third session.

Formative Assessment

Divide students into eight small groups and assign each group one of the fuel system components discussed in the lesson (primers, fillers, vents and overflows, tanks, gauges, selectors, strainers, sumps and drains). If fewer groups are preferred, have each group address more than one component of the fuel system. Give students time to review the material for their assigned component and come up with a plan to teach that material to the rest of the class. Encourage creativity. Students may write a song or rap, create a poster, develop a slide presentation, make a short video, or use some other creative means to teach the material. Give each group 2 minutes to present their "lesson" to the class.

[DOK 3; *apprise*]

EXTEND

Teacher Material: Fuel Systems Presentation

Slides 23-25: Different aircraft engines have different requirements. It's critical that the correct type of fuel be used. Turbine engines require jet fuel while most reciprocating engines use aviation gasoline, more commonly called avgas. Some aircraft may use diesel fuel or automobile gasoline, but these are relatively uncommon. To help ensure that the right fuel is placed in the tanks, fuels are color coded with dye and placards stating the correct type of fuel are placed near the fuel filler openings.

Jet fuel is kerosene based. It may be classified as Jet A or Jet B depending on the mix of ingredients. To help distinguish it from other fuels, it is clear or straw colored. When compared to gasoline-based fuels, such as avgas, it has a higher flash point, which means it requires a higher temperature to ignite.

Avgas comes in a variety of grades, but the most common is designated 100LL, which stands for 100 octane, low lead fuel. It is dyed light blue in color, as seen in the image on Slide 24. Because it contains a small amount of lead, the aviation industry is moving to find an unleaded replacement that will operate safely in most aircraft engines. Some aircraft can run on more than one grade of fuel, such as 100LL or 100 octane avgas. The image on Slide 22 shows an aircraft fuel filler placarded to run on either fuel grade. 100 octane avgas is dyed green while 80 octane avgas is dyed red.

A small number of reciprocating aircraft engines can run on diesel or automobile gasoline, but special permission is required to operate on auto gas.

Slide 26: The consequences of introducing improper fuel into an aircraft's tanks or not the right amount of fuel can range from the benign (fuel system drainage) to the expensive (engine replacement) to the disastrous (engine failure during flight). Given simple precautions, all are easily preventable.

Fixed base operators (FBOs) that provide fuel generally have line personnel to dispense the fuel. Be present every time your aircraft if fueled and observe the fueling process. At some airports, pilots may have the option of using a self-service fuel facility (this is like pulling up to a gas station and filling up your own car with gas). In either case, make sure the proper fuel grade and quantity is pumped into the airplane.

Slides 27-29: Observe these guidelines and practices when fueling your aircraft.

- Fuel Grade and Quantity - When line personnel is fueling an aircraft, specifically state the fuel grade and quantity to be placed in the aircraft. Always ask for a read-back of the fuel order from the FBO employee who took it. Match the fuel truck with the fuel ordered. If using a self-serve fuel facility, verify the type of fuel in the fuel pump being used.
- Fuel Nozzle - Check to verify the fuel nozzle is compatible with the aircraft's fuel filler. Avgas nozzles are small and round, while jet fuel nozzles are larger and flattened like a duck's bill at the end.
- Aircraft Grounding - Always make sure the airplane is grounded to the fueling source. Fuel passing through the hose builds up static electricity. Static electricity around gasoline can be explosive. Grounding the aircraft prevents static discharge from causing an explosion. Fuel trucks and fuel pumps have a special wire on a reel that is connected to the aircraft to ground it. Connect the grounding wire to unpainted metal on the aircraft; the engine exhaust is often a good choice, otherwise try the metal lugs on the nosewheel strut where the towbar attaches. Just as important, don't forget to disconnect the grounding line before taxiing away.
- Payment - When paying, verify the fuel grade and quantity on the invoice match what was ordered or what was intended.
- Preflight - Visually check the tanks for quantity and fuel color. Drain a generous sample from each tank sump. Check for water and other contaminants, and note the fuel smell and color. Remind students that if there are any doubts about the type of fuel in the tanks, do not depart. Ask students to recall the colors for 100LL (blue) and jet fuel (clear or straw-colored).
- Fuel caps - Finally, make sure the fuel caps are secure. If a fuel cap is lost in flight, fuel can siphon out of the tank at a very alarming rate. If flying a high-wing airplane or flying at night, a pilot won't be able to see it.

Slide 30: Complete the **Formative Assessment**.

Formative Assessment

Divide students into four groups. Assign each group a different type of fuel related accident (fuel starvation, fuel exhaustion, fuel contamination, or misfueling).

Information about aviation accidents related to these topics can be found on the NTSB website (https://www.ntsb.gov/_layouts/ntsb.aviation/index.aspx). At the bottom of this NTSB website in the "Event Details" section, students can enter their type of fuel related accident into the area reserved for word strings. Once they have typed in their type of accident and selected "Submit Query", a selection of related accidents will be presented. Students should select either the PDF or HTML "Final Report" link to read an analysis and summary of each accident.

Each group of students should select one accident related to their type of fuel related accident. Students may use information from official NTSB accident reports, news articles, or other sources. Each group should develop a poster, slide presentation, or storyboard to present its findings to the class. Presentations should include information about circumstances surrounding the accident, the role of fuel in the accident, additional causes of/contributors to the accident, and ideas for how the accident might have been prevented.

This NTSB safety alert may provide helpful background regarding misfueling and how to prevent such accidents: https://www.ntsb.gov/safety/safety-alerts/Documents/SA_050.pdf

[DOK 3; *investigate, formulate, apprise*]

EVALUATE

Teacher Materials: Fuel Systems Presentation, Fuel Systems Teacher Notes
Student Material: Fuel Systems Student Activity

Slides 31-36: Review private pilot knowledge test questions and answers with students.

Slide 37: Complete the **Summative Assessment**.

Summative Assessment

In the summative assessment, students will review a preflight checklist and identify the items related to fuel and fuel systems. For each checklist item, students will describe why a pilot should perform this check. In addition, students will describe the differences between avgas and jet fuel and they will also describe three guidelines that pilots should follow in order to safely fuel an airplane.

Provide each student with a copy of **Fuel Systems Student Activity.** Answers can be found on **Fuel Systems Teacher Notes**.

[DOK 3, *differentiate; assess;* DOK 2, *summarize*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Student work shows evidence of understanding regarding:
  - Why performing preflight inspections related to fuel systems is critical to flight safety
  - The differences between the two main types of aviation fuel

    - How to properly fuel an airplane and important safety considerations that should be followed
- Contributions show understanding of the concepts presented in the lesson
- Contributions show in-depth thinking including analysis or synthesis of lesson objectives

Points	Performance Levels
9-10	Consistently demonstrates criteria
7-8	Usually demonstrates criteria
5-6	Sometimes demonstrates criteria
0-4	Rarely to never demonstrates criteria

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

- **HS-ETS1-2** - Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering
    - Science and Engineering Practices
        - Asking Questions and Defining Problems
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.A: Defining and Delimiting Engineering Problems
    - Crosscutting Concepts
        - None
- **HS-ETS1-3** - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
    - Science and Engineering Practices
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.B: Developing Possible Solutions
    - Crosscutting Concepts
        - None

COMMON CORE STATE STANDARDS

- **RST.9-10.2** - Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- **RST.9-10.4** - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.
- **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.
- **WHST.9-10.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- **WHST.9-10.9** - Draw evidence from informational texts to support analysis, reflection, and research.

REFERENCES

https://elearning.aopa.org/client/app.html#/courses/70001?module=70001&section=100016
https://www.aopa.org/training-and-safety/students/presolo/skills/checking-fuel-samples
https://www.ntsb.gov/safety/safety-alerts/Documents/SA_050.pdf
https://www.aopa.org/training-and-safety/students/presolo/skills/refueling-procedures