THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Department of Aeronautical and Aviation Engineering
航空及民航工程學系

Introduction to Aircraft Systems

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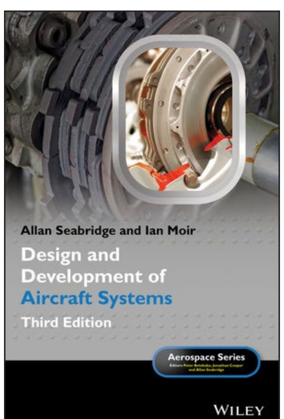
	Date	Content		Assignment
1)	17-Jan-25	• Overview		
2)	24-Jan-25	• Aircraft Control Systems		
3)	07-Feb-25	• Aircraft Landing Gear Systems	Assignment 1	
4)	14-Feb-25	• Aircraft Engine System		DDL for Assignment 1
5)	21-Feb-25	• Aircraft Fuel Systems		
6)	28-Feb-25	• Aircraft Hydraulic Systems	Assignment 2	
7)	07-Mar-25	• Aircraft Electric Systems • In-Class Quiz (closed book)		DDL for Assignment 2
8)	14-Mar-25	• Atmospheric Conditions	Course Project	
9)	21-Mar-25	• Aircraft Pneumatic Systems • Aircraft Environmental Control System	Assignment 3	
10）	28-Mar-25	• Aircraft Environmental Control System • Aircraft Emergency System		DDL for Assignment 3
11）	04-Apr-25	• Public holiday		
12）	11-Apr-25	• Reserved for guest lectures/Avionics systems		
13）	18-Apr-25	• Public holiday		DDL for Course Project

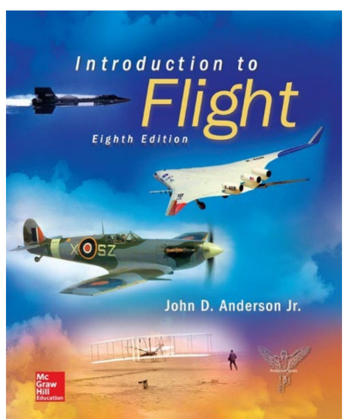
Relevant courses in AAE

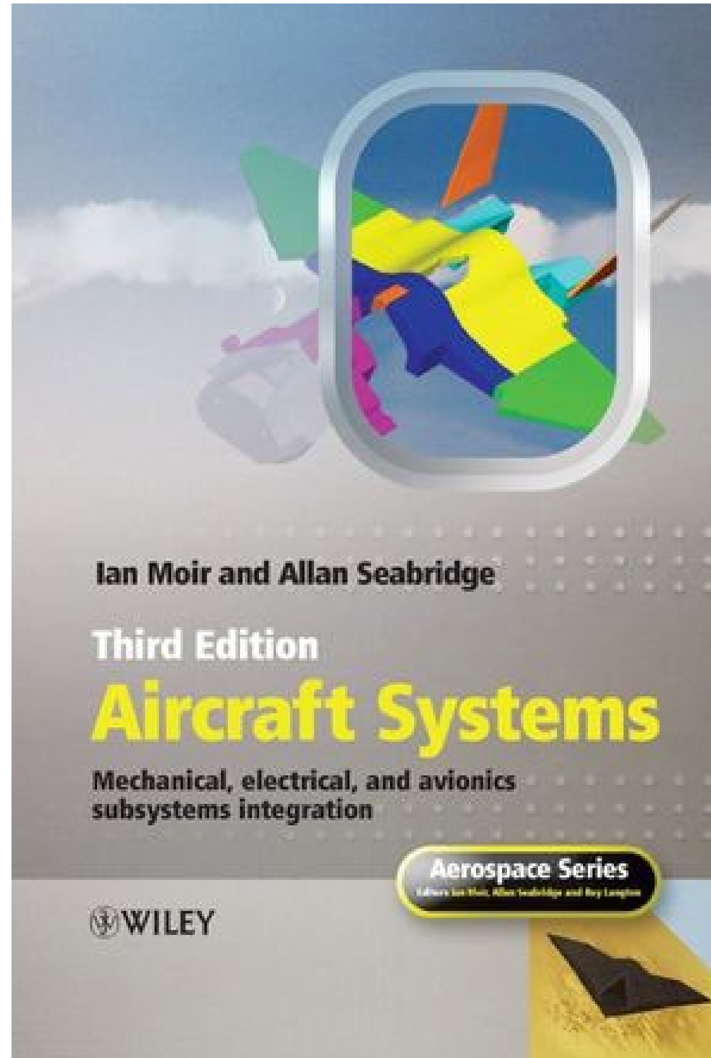
- AAE 2005: Electrics and Electronic for Aeronautical Engineering
- AAE 3003: Aircraft Propulsion Systems
- AAE 3008: Fundamental Thermal-Fluid Science
- AAE 3011: Aircraft Performance and Flight Management
- AAE 4301: Avionics Systems
- AAE 4113: Aerospace Propulsion
- AAE 4110: Aircraft Propeller
- AAE 5203: Aircraft Design and Certification

Reference and reading list

- **I. Moir and A.G. Seabridge, Aircraft Systems: Mechanical, Electrical, and Avionics Subsystems Integration, 3rd edition, Wiley, 2011**.
- I. Moir and A.G. Seabridge, Design and Development of Aircraft Systems AIAA, 2020.
- J. Anderson, Introduction to Flight, 9th edition, McGraw Hill, 2021.

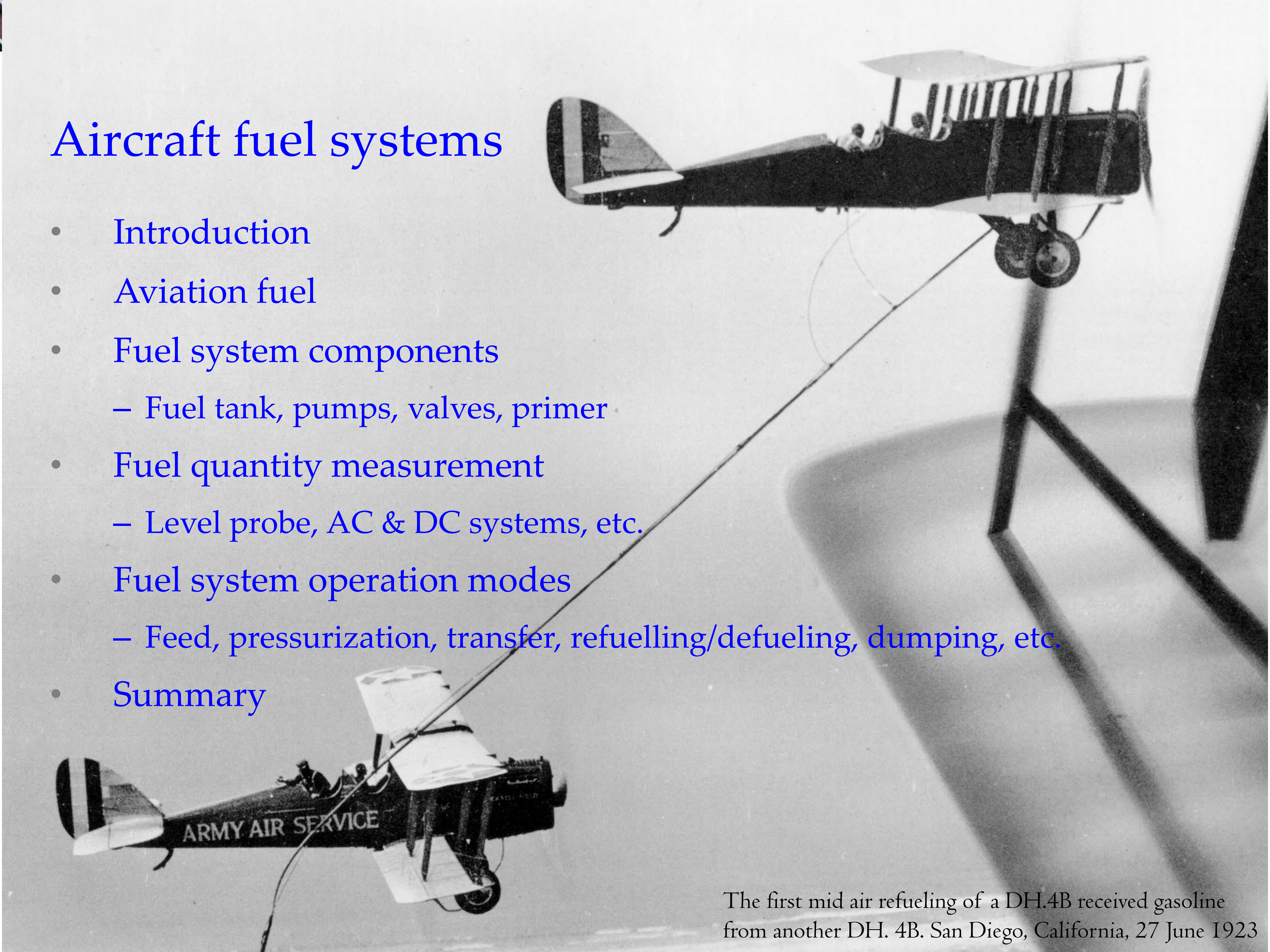






Aircraft fuel systems

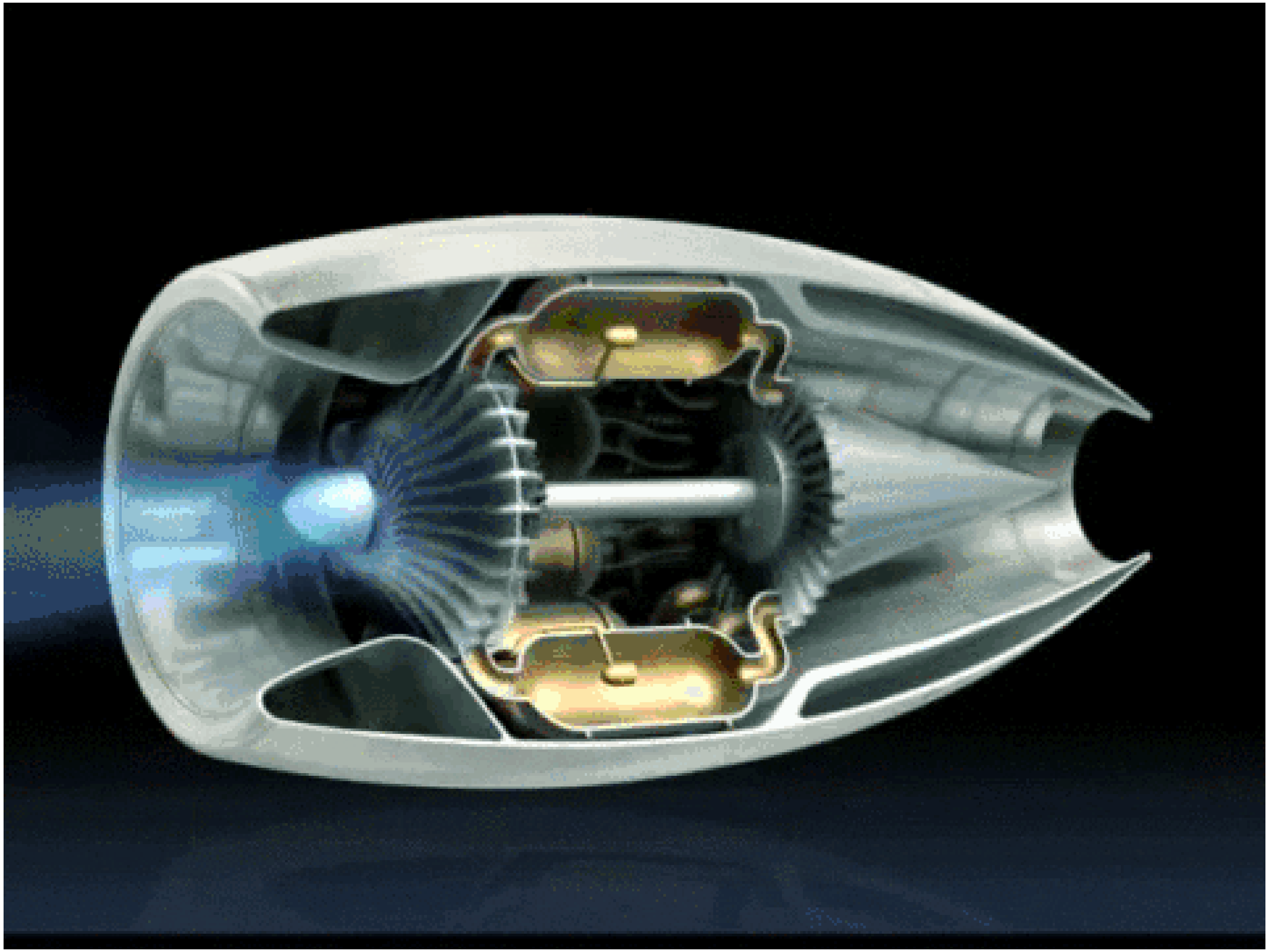
- Introduction
- Aviation fuel
- Fuel system components
  - Fuel tank, pumps, valves, primer
- Fuel quantity measurement
  - Level probe, AC & DC systems, etc.
- Fuel system operation modes
  - Feed, pressurization, transfer, refuelling/defueling, dumping, etc.
- Summary



The first mid air refueling of a DH.4B received gasoline from another DH. 4B. San Diego, California, 27 June 1923

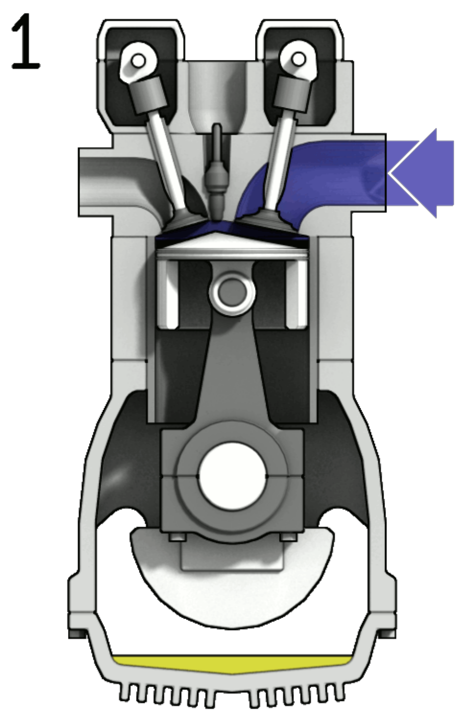
Introduction

Introduction



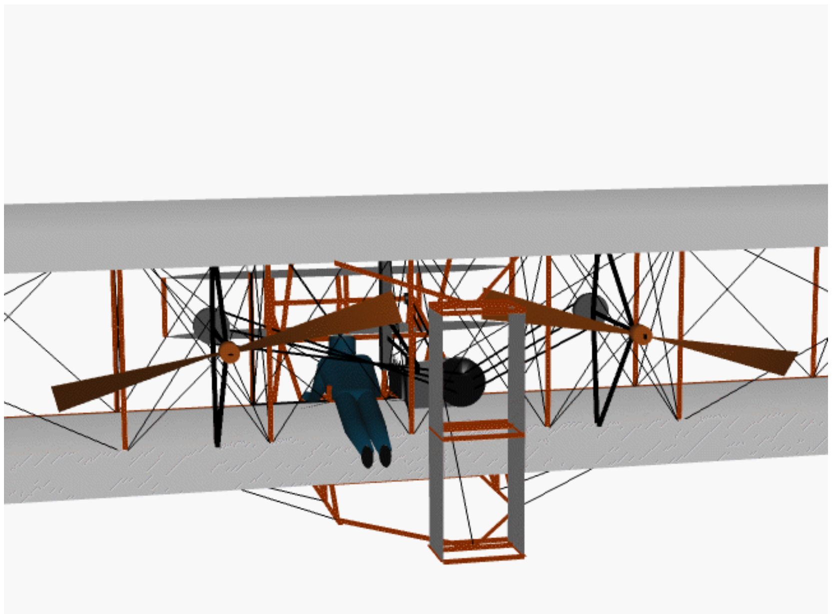
Introduction

- In an engine, fuel is well mixed (vaporized) with air and burned. The resulting gas expansion do work that drives the motion.

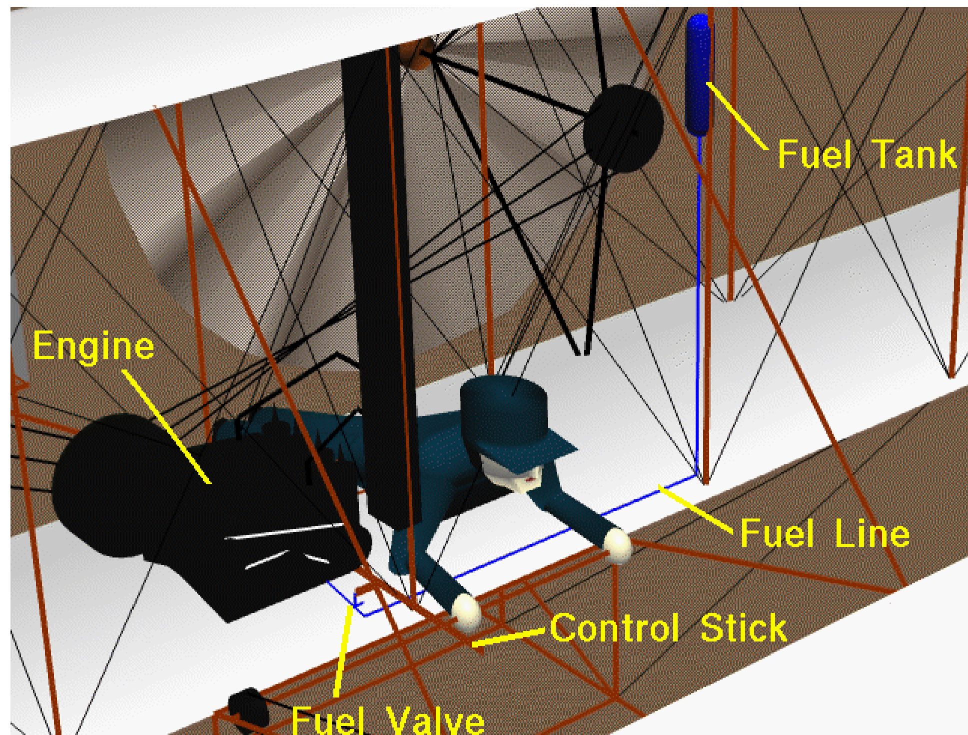


- The aircraft fuel system denotes the units and components which store and deliver fuel to the engine.
- It can include the fuel containing and transportation components, and many other parts to realize the fuel supply functionality.

Fuel system of the Wright Flyer fuel system

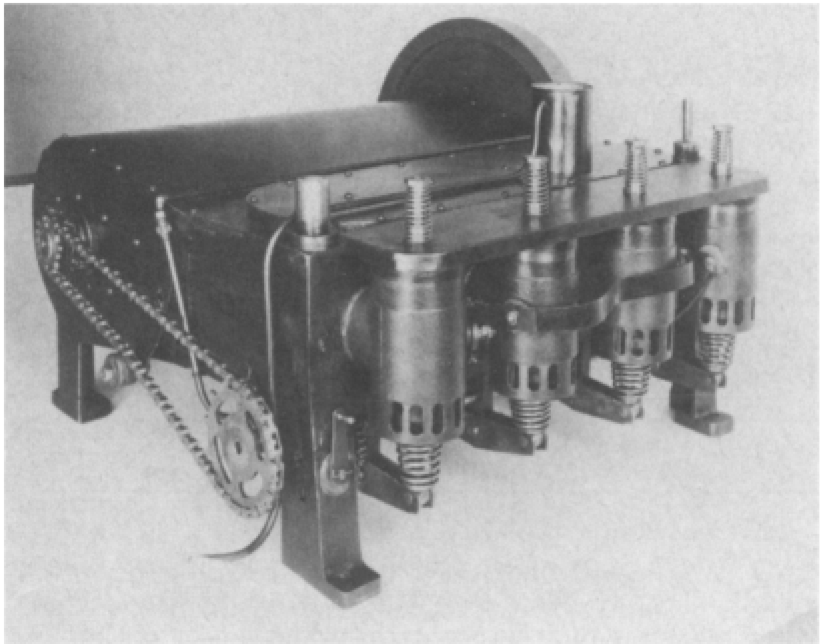


To generate thrust for their aircraft, the Wright brothers used twin, counter-rotating propellers at the rear of the aircraft to turn the propellers



https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/fuel-system/

Introduction

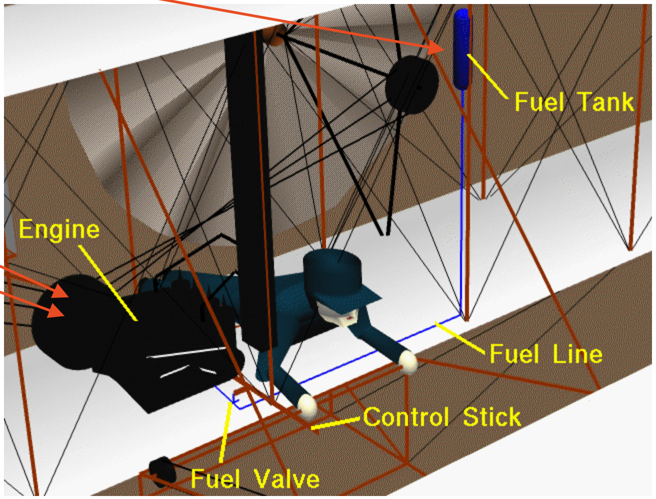


The 4-stroke, 4-cylinder gasoline-powered internal combustion engine used on Wright Flyer 1

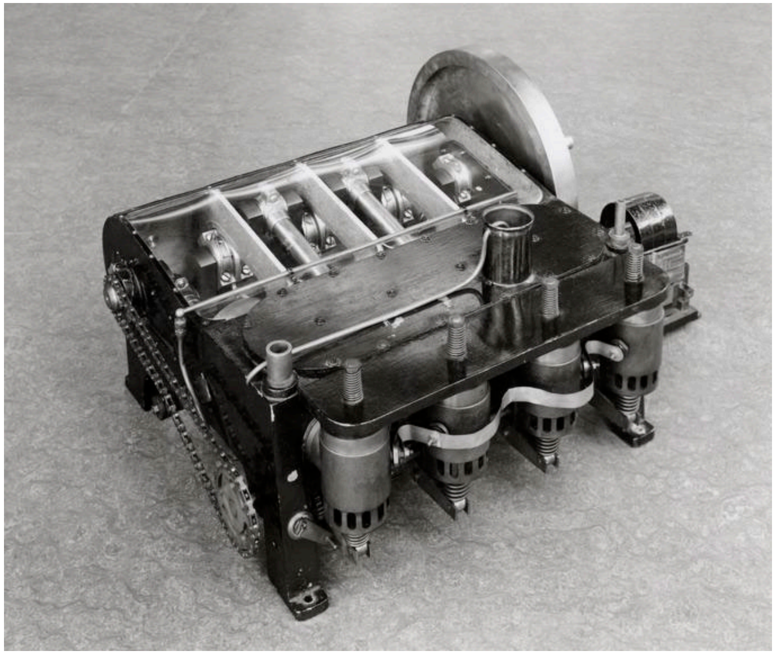
Introduction

- In any internal combustion engine, fuel and oxygen are combined in a combustion process to produce the power to turn the engine.
- The fuel system is to mix the fuel and oxygen for combustion and to distribute the fuel/air mixture to the combustion chambers.
- In Wright Flyer I, the fuel system contains:
  - a fuel tank and line mounted on the airframe
  - a carburetor in which the fuel and air are mixed
  - an intake manifold which distributes the fuel/air mixture to the combustion chambers.

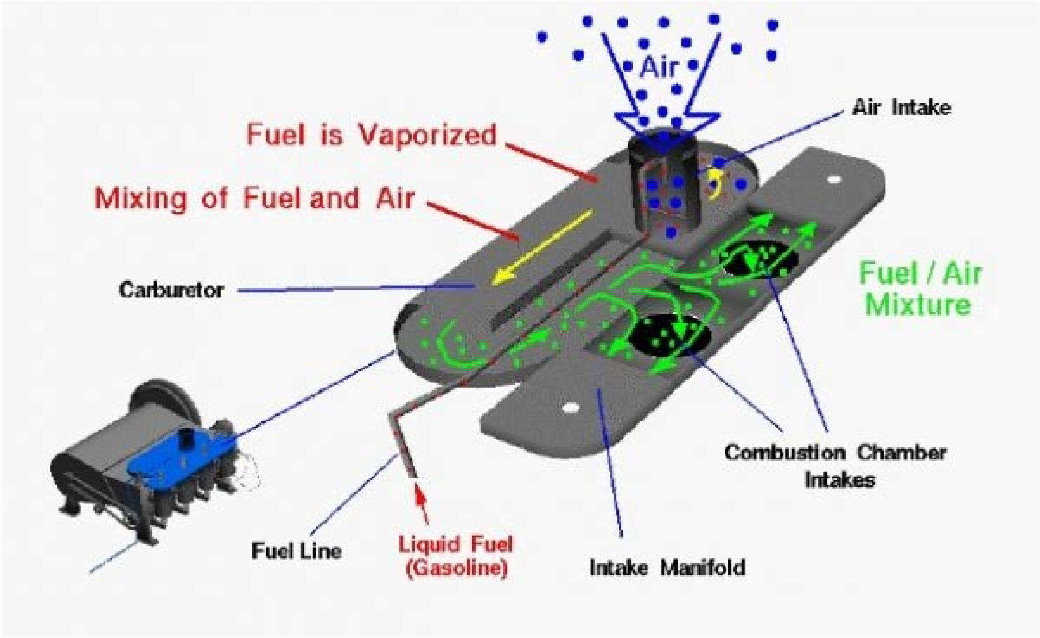
Close to the engine



Introduction



Replica of 1903 Wright Brothers' aero engine

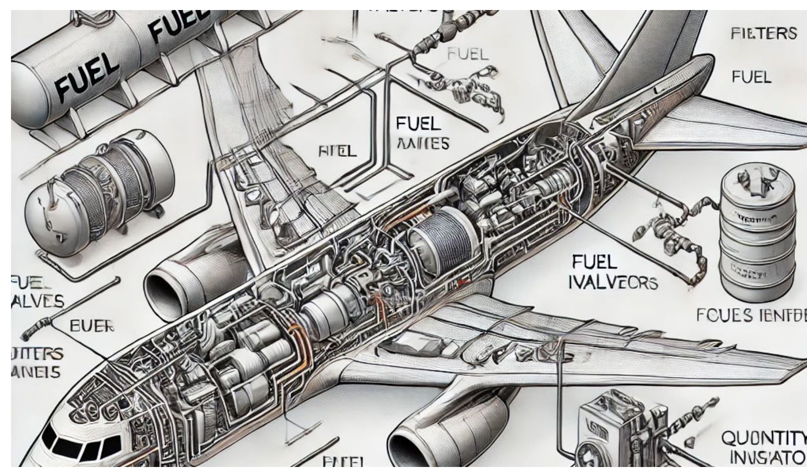


For Wright Flyer I:

- The tank is mounted high, and the fuel is fed to engine by gravity
- Fuel flows through a small metal fuel line from the tank to the engine.
- The flow of fuel to the engine is controlled by a fuel valve located on the fuel line.

Introduction

- At the early date, the fuel system and structures were relatively simple:
  - Gravity fed
  - Simple tank configurations and indications
- With the increase of aircraft performance, the fuel system become more complex:
  - Booster pumps
  - Tank configurations
  - Multi-valve systems



Introduction

- With the deployment of the jet turbine powered engines, the fuel consumption is very fast, leading to the requirements in:
  - More accurate fuel gauging systems: to ensure more reliable fuel control
  - Greater fuel delivery pressures: to avoid cavitation and flame-out
  - New fuel system arrangements: under-wing or under-fuselage configurations.
- All of these features also lead to the requirement in more complex valve structures and various sensors.

In-flight fuelling/Aerial refuelling

Handley Page Harrow aerial refuelling tanker conversion G-AFRL topping up Imperial Airways Short S.30 flying boat "Cabot" G-AFCU over Ireland in 1939

Aerial refuelling of the military aircraft

Introduction

- The purpose of the fuel system is to provide a **reliable fuel supply** to engines. It is an essential parts in the overall aircraft systems to ensure the flight safety and performance.
- An aircraft fuel system usually contain one or all of the following modes
  - Fuel pressurization
  - Engine feed
  - Fuel transfer
  - Fuel storage
  - Vent system
  - Fuel jettison
  - In-flight refueling, etc.

It is necessary that we introduce the a fuel properties, key components in fuel system and finally the operation modes

Aviation fuel/航空燃油

Aviation fuel

- Aviation fuels are petroleum-based fuels, or petroleum and synthetic fuel blends, to power aircraft.
- Compared with fuels used for heating or ground transportation, there are more requirements for the aviation fuel.
- They also contain additives to enhance or maintain properties for fuel performance or handling.
  - E.g., the piston-engine aircraft may use leaded gasoline

Additive example: leaded gasoline

- When gasoline is used in high-compression internal combustion engine, it can suffer from the engine knocking(敲缸/爆震).
  - Engine knocking is caused by the combustion does not result from the flame propagation. It can destruct the engine.
- To address this problem, tetraethyllead (TEL,四乙基鉛) was widely used as additive since 1920s.
- However, TEL can cause environment problem:
  - Study shows a correlation of lead content of human blood and violent crime
  - Since 1986, leaded fuel was banned for on-road fuel use
  - Since 1990s, leaded fuel was banned in the entire EU with the exception for AVGAS 100LL for general aviation.

Characteristics of the aircraft fuel system

- Basic properties of the aircraft fuels:
  - Volatile/揮發性: tendency to change from liquid to vapour
  - Vapour pressure: at which the fuel vaporises
  - Flash point/閃點: lowest temperature that the vapours above the liquid is ignited without sustaining a flame
  - Fire point/燃點: lowest temperature at which the fuel can sustain combustion
  - Freezing point/凝固點: a state the ice crystals disappears when it warms up

Characteristics of the aircraft fuel system

- The specific gravity (SG) of is also a parameters used for quantity the fuel:

$$\mathrm{SG} = \frac{\rho_{\mathrm{fuel}}}{\rho_{\mathrm{water}}}$$

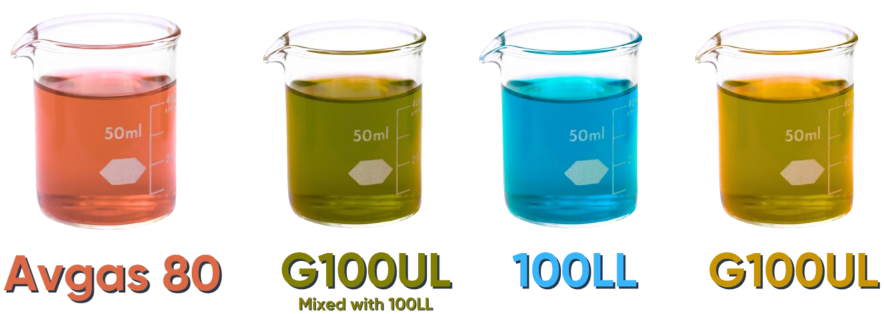
  - At 15℃, the SG of AVGAS is about 0.74
  - At 15℃, the SG of AVTUR is about 0.75-0.84
- The SG can affect the total weight of the aircraft and affect the flight range

Types of aviation fuel: AVTUR/航空煤油

- Jet fuel, or aviation turbine fuel (ATF), or AVTUR:
  - A clear to straw-colored fuel
  - It can be used in either turbine engines or compression ignition engine
- AVTUR is often used in jet engines
- Common types of AVTUR (based on properties such as freezing and fire points, etc.)
  - Jet A-1 (unleaded kerosene): widely used in the world except for Russia.
  - Jet B: used for the enhanced cold-weather performance as the freezing point is low as -60℃. But it is dangerous as well because the flash point is also low.
  - GOST standards: mainly used in Russian
  - RP-3: a standard defined by China with close performance as Jet A-1

Types of aviation fuel: AVGAS/航空汽油

- AVGAS is short for Aviation Gasoline. In the UK, it is also called aviation spirit.
- It is used in aircraft with internal combustion engines.
- Unlike the gasoline used for moto-vehicles, AVGAS still contain tetraethyllead (TEL) to prevent the engine knocking.
- AVGAS is classified based on the amount of TEL:
  - AVGAS 80/87: (0.5g TEL/gallon), used for low compression ratio engine
  - AVGAS 100/130: (4g TEL/gallon)
  - AVGAS 100LL (low lead, 2g TEL/gallon): most widely used for aviation



To make it easier for pilots to distinguish different types of AVGAS, dyes are added.

Fuel Type and Grade	Color of Fuel	Equipment Control Color	Pipe Banding and Marking	Refueler Decal
AVGAS 82UL	Purple	82UL AVGAS	AVGAS 82UL	82UL AVGAS
AVGAS 100	Green	100 AVGAS	AVGAS 100	100 AVGAS
AVGAS 100LL	Blue	100LL AVGAS	AVGAS 100LL	100LL AVGAS
JET A	Colorless or straw	JET A	JET A	JET A
JET A-1	Colorless or straw	JET A-1	JET A-1	JET A-1
JET B	Colorless or straw	JET B	JET B	JET B

Emerging types of aviation fuel

- Biofuels, also known as the sustainable aviation fuel (SAF): alternative to conventional fossil-based fuels. They are made from biomass to liquid method
  - Requires few or no modifications to the aircraft fuel system
  - Yields lower emissions of particles and green-house gases
  - Expensive
- Compressed natural gas (CNG)
  - Boeing Subsonic Ultra Green Aircraft Research Team
- Liquid hydrogen

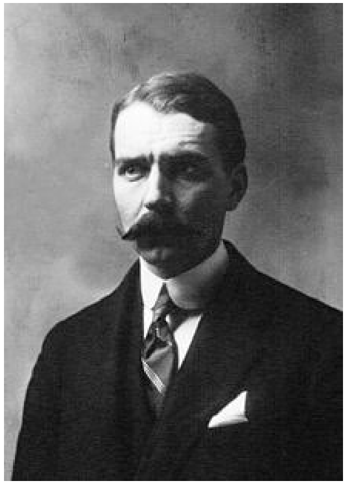
Fuel fraction

Breguet Range Equation

- For an aircraft at the level flight speed V, the lift to drag ration is L/D, the initial and final weights are W_i and W_f.
- The flight range R can be estimated as:

$$R = V \cdot \left(\frac{L}{D}\right) \cdot \left(\frac{1}{g \cdot b_f}\right) \cdot \ln\left(\frac{W_i}{W_f}\right)$$

- b_f is determined by the propulsion system.



Louis Charles Breguet (1880–1955): French aircraft designer and builder, one of the early aviation pioneers.

- Development of reconnaissance aircraft during WWI

He won a bronze medal in sailing during the 1924 Summer Olympics.

Fuel fraction

- The fuel fraction, also called the fuel weight's fraction, is the weight of the fuel divided by the gross take-off weight of the aircraft:

$$\xi = \frac{\Delta W}{W_i} = \frac{W_i - W_f}{W_i}$$

- It is the key parameter to determine the aircraft's range, which is the distance it can fly without refuelling.
- Based on Breguet's range equation, the flight distance is

$$R \propto -\ln(1 - \xi)$$

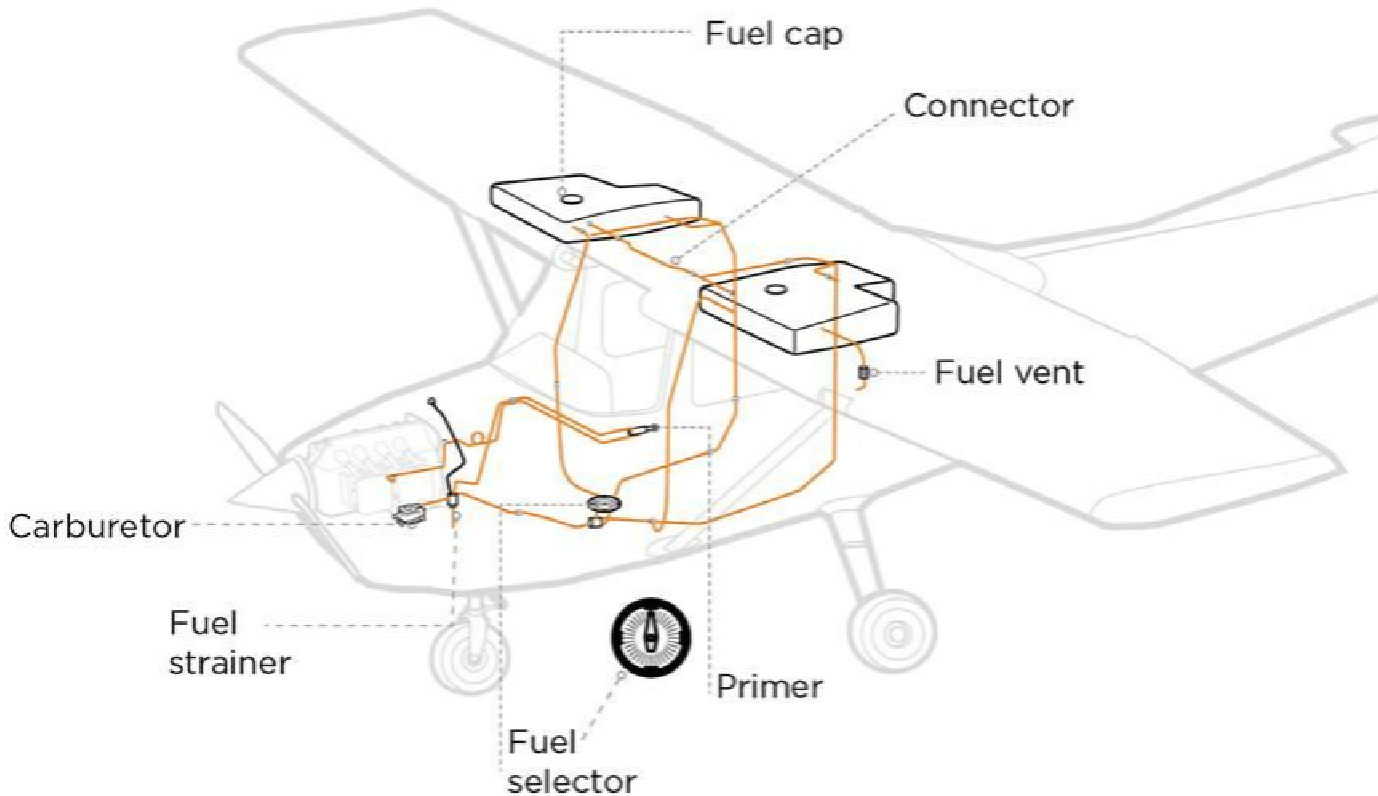
- For civil aircraft, the value is between 26% (medium-haul) to 45% (long-haul).

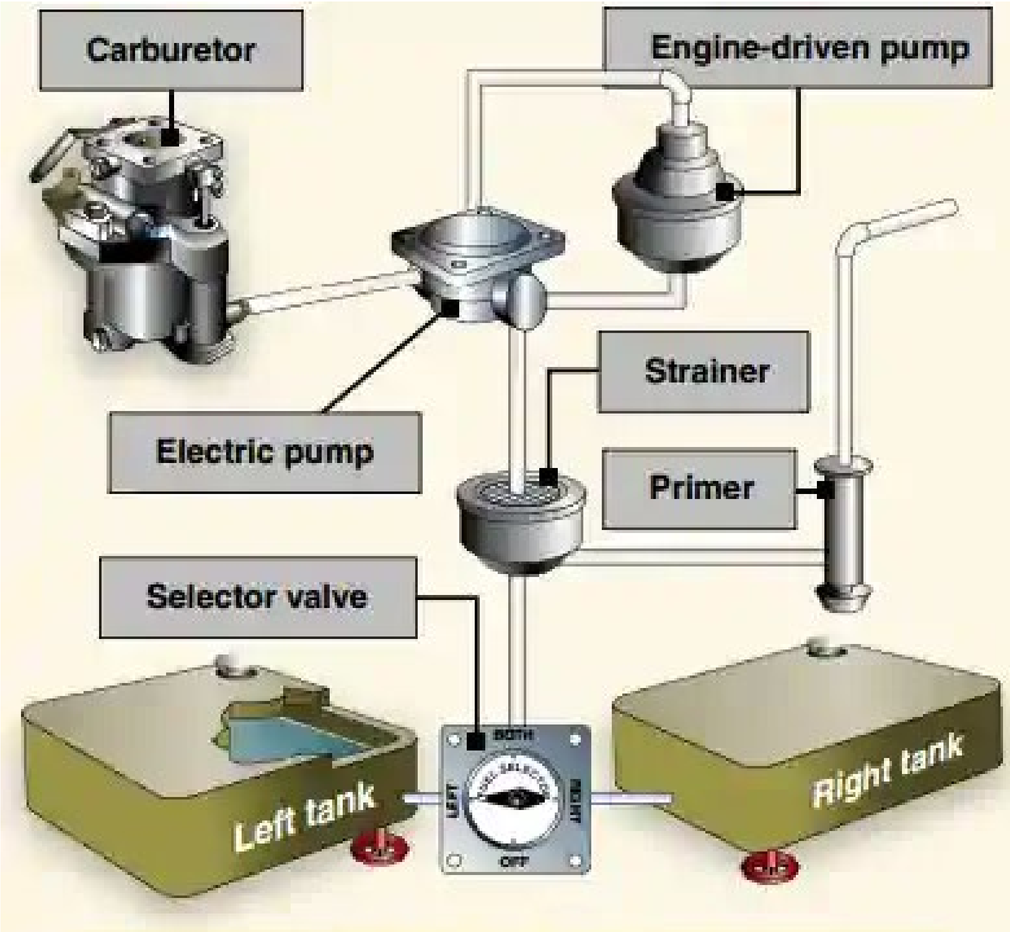
$$R = V \cdot \left(\frac{L}{D}\right) \cdot \left(\frac{1}{g \cdot b_f}\right) \cdot \ln\left(\frac{W_i}{W_f}\right)$$

Fuel system components

Fuel system components

- In this part, we introduce the key components in an aircraft fuel system, including:
  - Fuel tanks
  - Fuel primer
  - Fuel pump
  - Fuel valves
  - Fuel vents
  - Carburetor

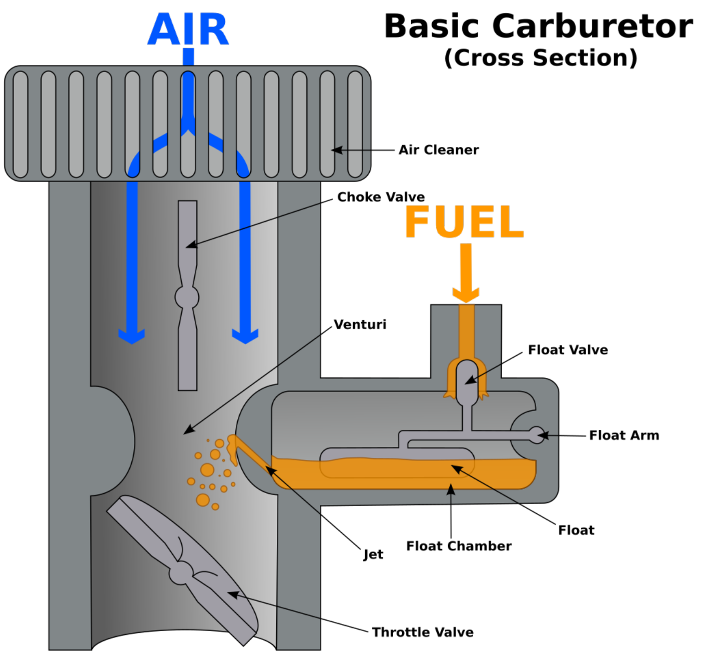




Fuel-pump system

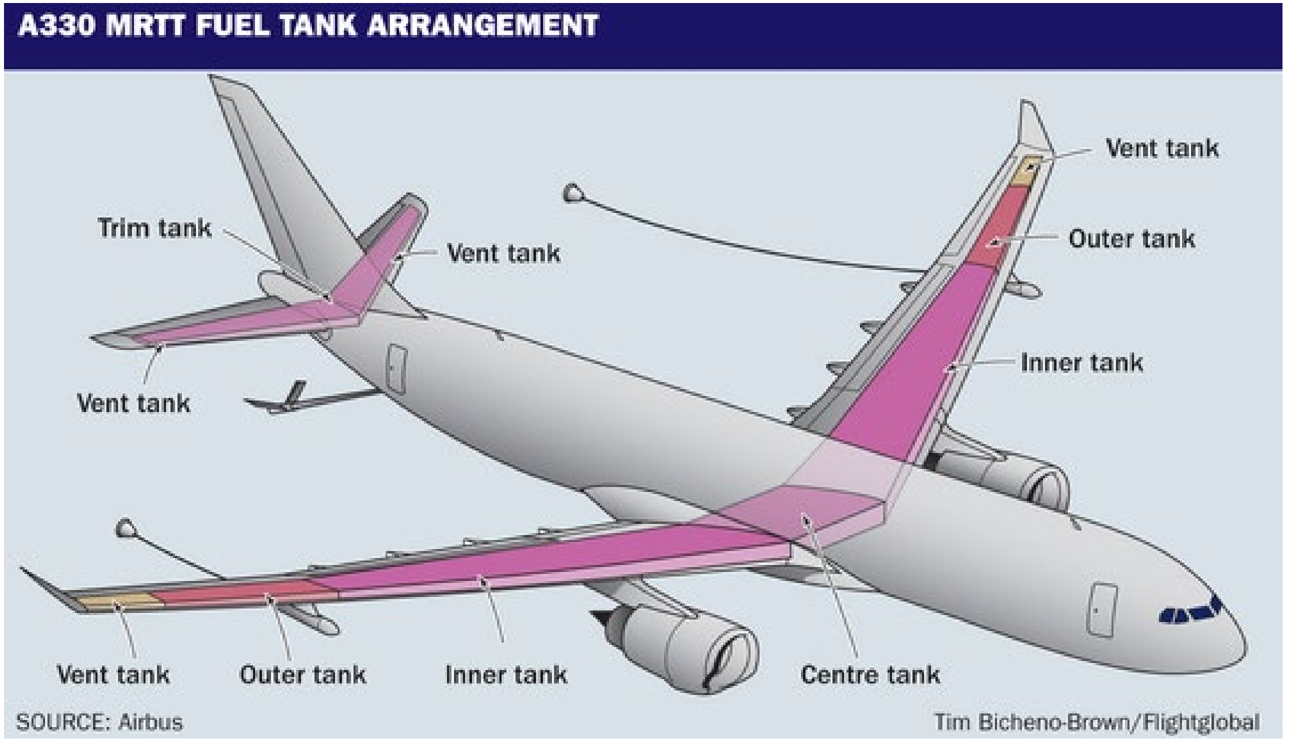
Carburetor/化油器

- Carburetor is a device used by gasoline internal combustion engine to control the mix air and fuel entering the engine
- Based on Bernoulli's principle, when the air speed is high, the pressure will be low. Then the fuel will be injected to the chamber.
- Since 1990s, carburetor is replaced by fuel injectors for motor vehicles. But they are still widely used in piston-engine-driven aircraft



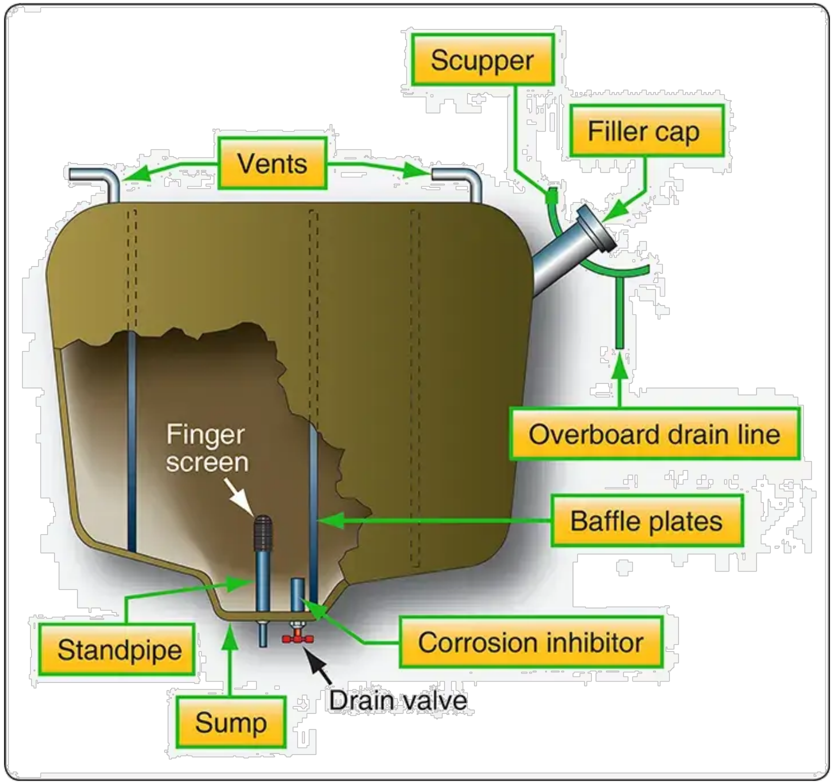
Fuel tanks/油箱

- Fuel tanks are the devices to store and supply the fuel on an aircraft
- The types and sizes can have a large variant
- Possible locations of fuel tanks:
  - Wings (normally)
  - fuselage
  - tails, etc.



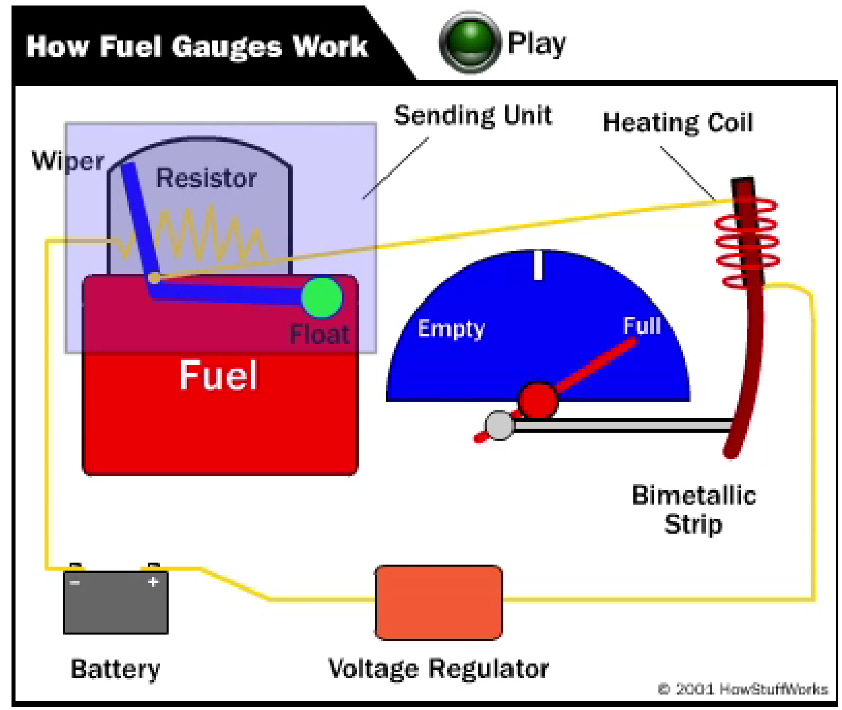
Fuel tank

- Major parts and functionalities:
  - Filler cap: it is used to cover the opening
  - Vents: to maintain the pressure with the outside atmosphere
  - Overflow drain: allow the fuel to expand with temperature increase



Fuel tank: fuel gauge/燃油表

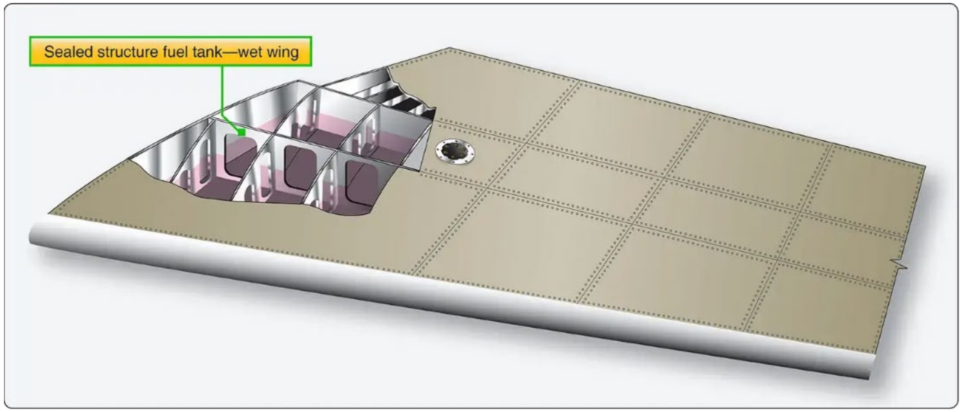
- **Fuel gauge**: The quantity is of the fuel in the tank is sensed and display before and during the flights
- It can contain two parts:
  - Sensors: in the tank
  - Indicators: on the dashboard



https://auto.howstuffworks.com/fuel-gauge.htm#pt2

Fuel tank: integral tanks (wet wing)/機翼整體油箱

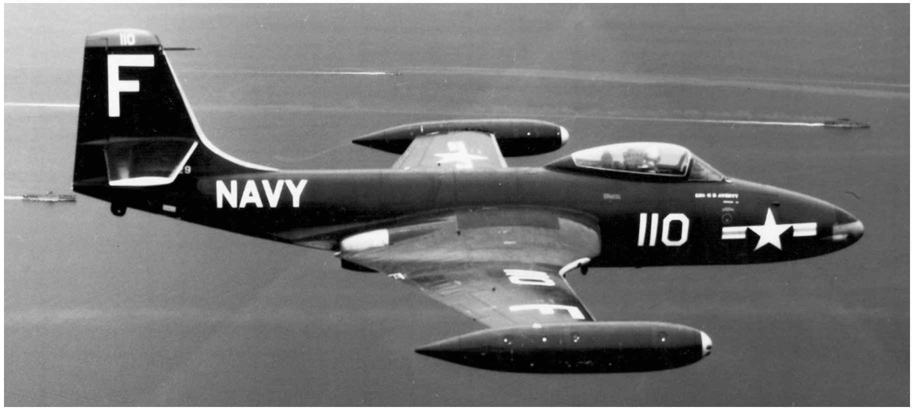
- Integral tanks, or wet wings, are made by sealing off the compartments inside the wings
- They uses the existing aircraft structure to contain fuel, and thus reduce weight
- Wet wing is a common configuration in large aircraft. Some strike aircraft such as Grumman A-6 Intruder also uses wet wing.



Grumman A-6 Intruder

Fuel tank: external wing tanks/副油箱-at wing tip

- These tanks are mounted externally, they are also call drop tanks
- For those at the wing tip, they are also called the tip tanks.
- Tip tanks can also improve the aerodynamic performance as winglets



F2H-3/4

winglet

Fuel tank: external wing tanks/副油箱-under wing

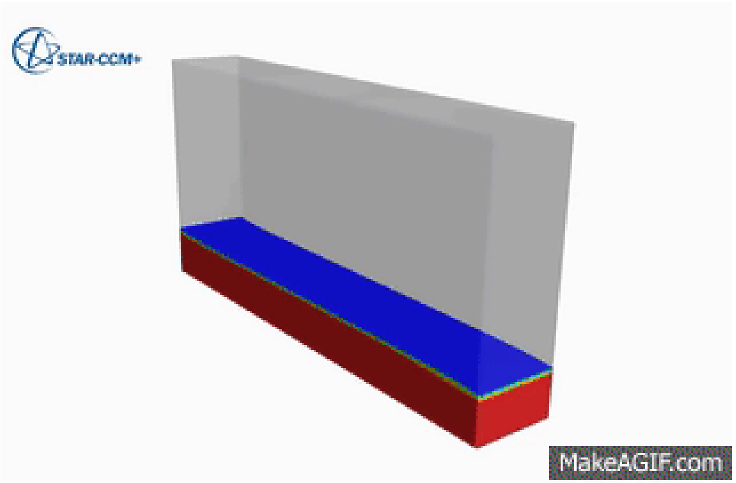
- Some wing tanks are placed externally underneath the wings.
- Sometimes they might be incorrectly recognized as weapons in fighters.

F-4E Phantom

This type of tanks belong to drop tank, which can be expendable and jettisonble.

Fuel tank: collector tanks/燃料收集箱

- Aircraft with long wings, where tanks can be installed, can suffer from the fuel starving due to sloshing

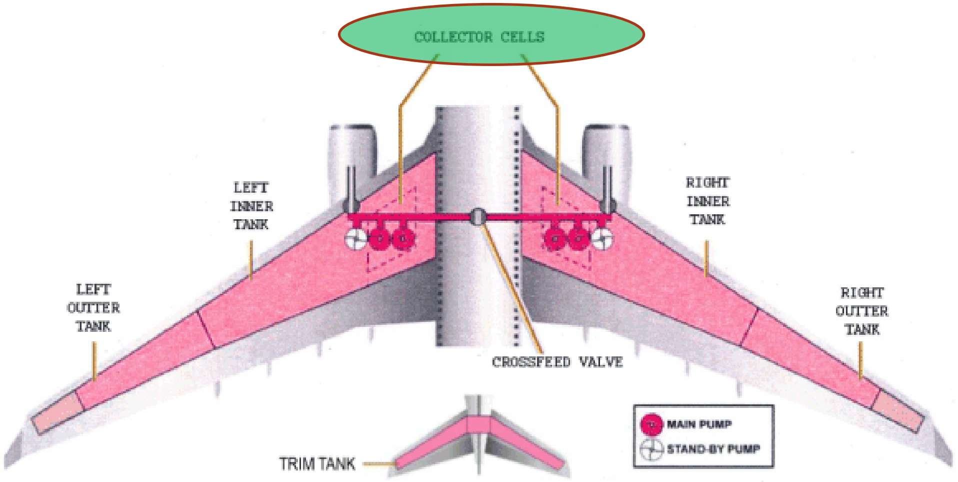


- Fuel starvation means the failure of fuel system to provide enough fuel for the engine operation, which can be caused by:
  - Blockage
  - vapor lock
  - Contamination by water, etc.
- There are still fuels in tanks, but the engine is not able to use it.
- By contrast, fuel exhaustion means the fuel is used up.

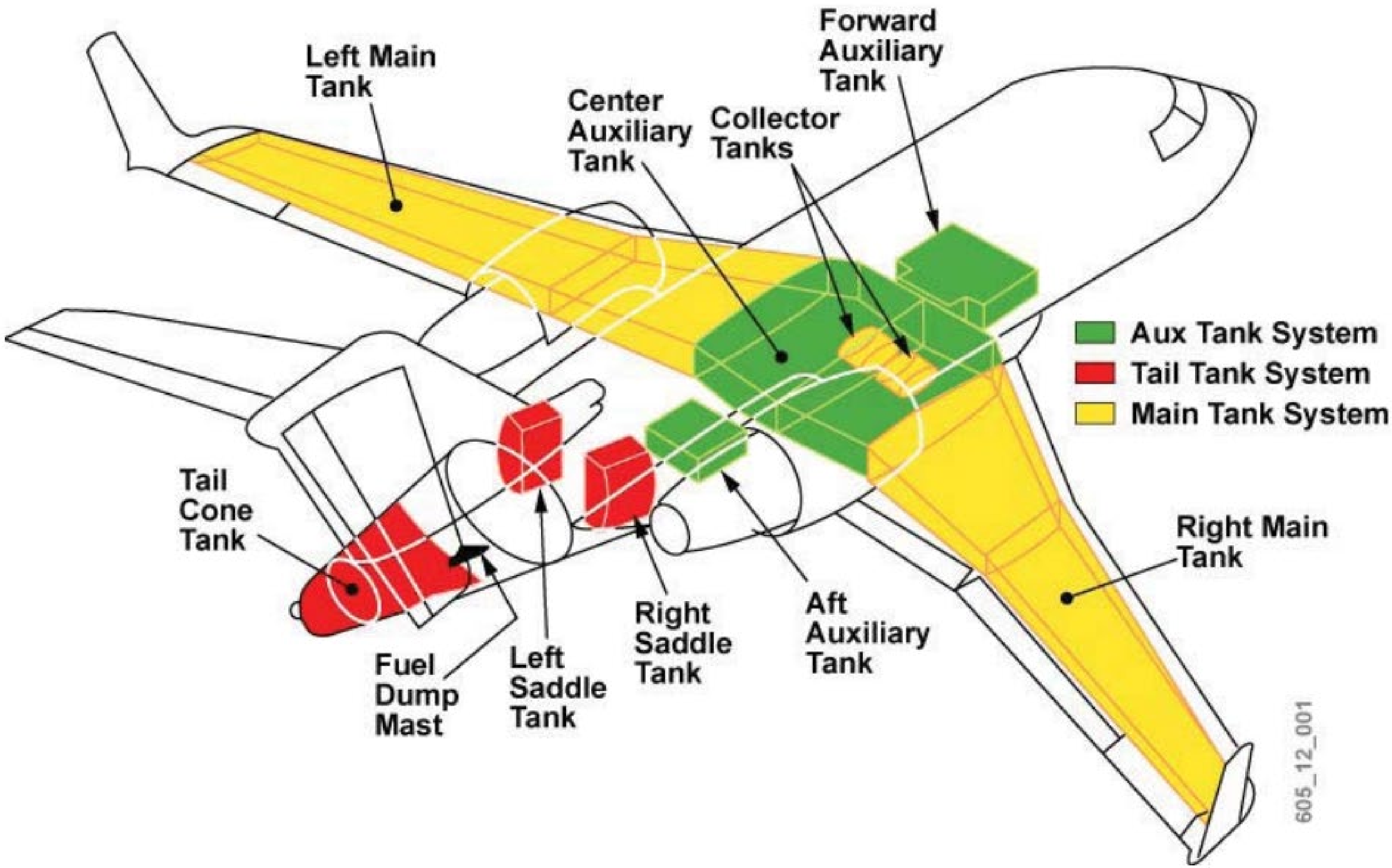
British Airways Flight 38 crash-landed at London Heathrow in 2008 after its fuel lines became clogged with ice crystals.

Fuel tank: collector tanks

- A solution to this problem, i.e., fuel starving due to the sloshing, is the use of the collector tanks in the system
  - The fuel goes to the collector tanks before going the engines
  - The smaller collector tank is always full of fuel that suppress any fluctuations in the fuel flow due to sloshing



Fuel tank: collector tanks



Fuel tanks & safety

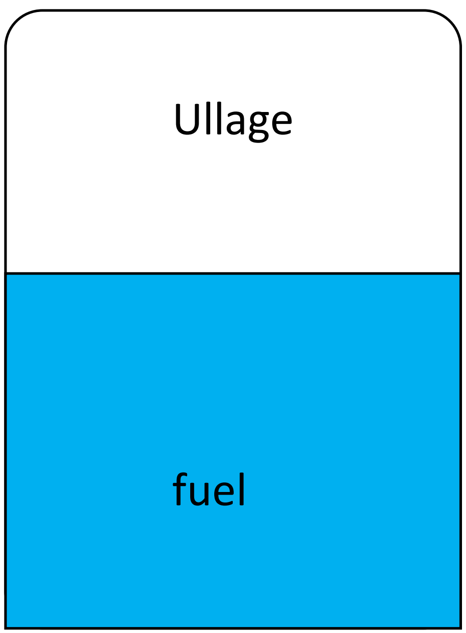
- Fuel tanks are implicated in aviation disaster, and they are causes for many accidents or worsening it (possible explosion)
- Faulty wiring(接綫錯誤) can be ignition source within the tank

The explosive fuel/air mixture was created in one of the aircraft's fuel tanks. Faulty wiring then provided an ignition source within the tank, destroying the airliner.

Flight accident of the TWA Flight 800

Fuel tanks & safety

- To reduce the tank explosion, two possible methods:
  - Fuel tank inerting system/惰性化系統: to decrease the possibility of combustion of flammable materials
  - Fire fighting foam in the tanks



Schematic of the inerting system：

- Usually, the ullage is filled air (oxygen) to support combustion. When needed, the inerting system replace the air with a gas that cannot support combustion, e.g., nitrogen.

Fuel tanks & safety

- In Boeing 737, two systems to reduce the tank ignition:
  - The first one shuts off fuel pumps when the output pressure is low to prevent the tank from over heating
  - The second one enriches nitrogen levels in the air of the fuel tank to suppress the burning.

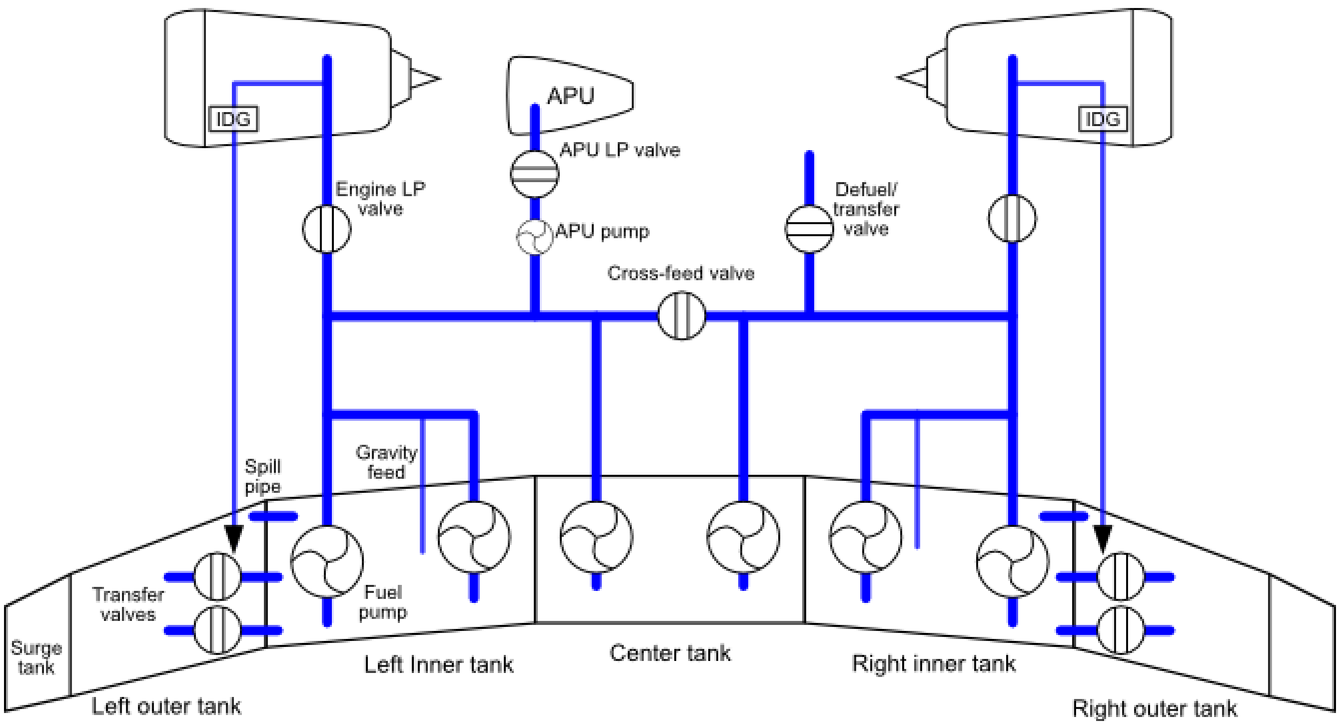
Oil pressure is measured before the bearings; and oil quantity at the tank, which drops after engine start. If the oil pressure is ever at or below the red line, the LOW OIL PRESSURE light will illuminate and that engine should be shut down.

Fuel primer/啓動注油閥

- A fuel primer is used to draw the fuel from the tanks to the combustion chamber directly:
  - During cold weather, the engine is hard to start because not enough heat is provided. The fuel primer is used in this situations.
- It might be used in the gravity-feed and fuel pump systems.

Fuel-injected engines do not require a primer.

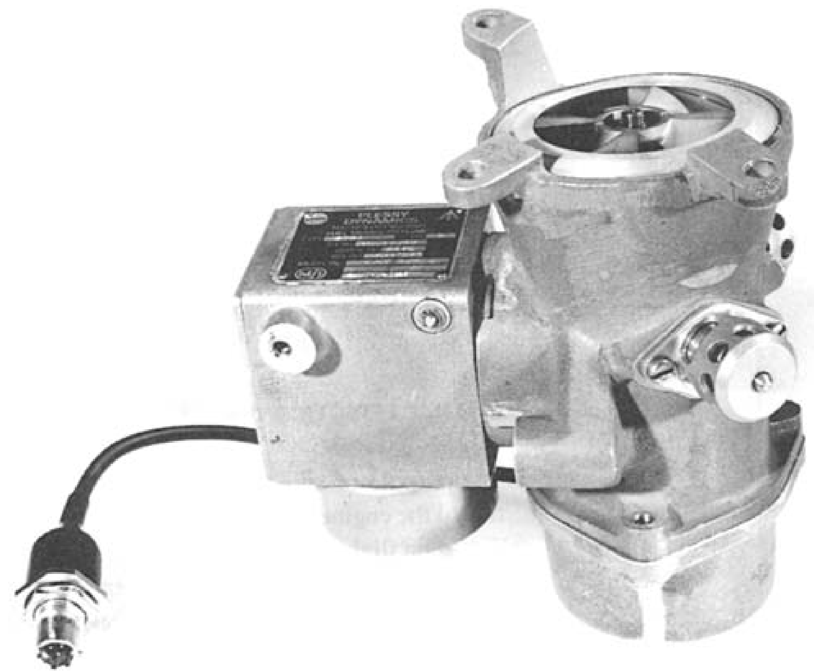
Fuel pump



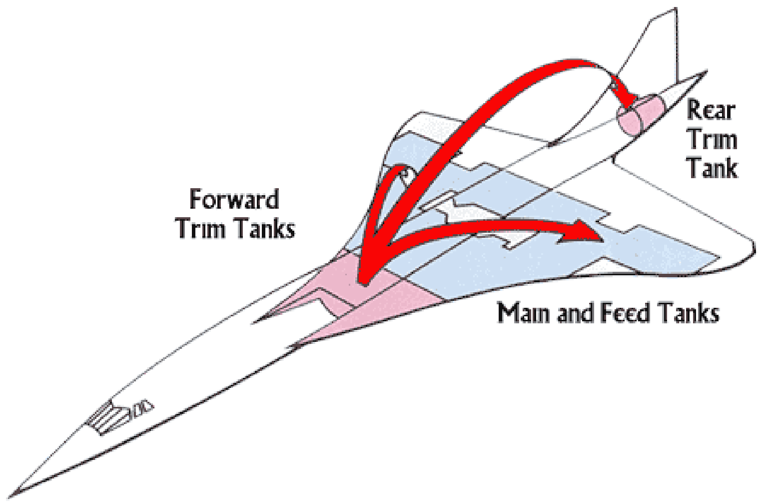
APU
IDG
IDG
APU LP valve
Engine LP valve
APU pump
Defuel/ transfer valve
Cross-feed valve
Gravity feed
Spill pipe
Transfer valves
Fuel pump
Surge tank
Left outer tank
Left Inner tank
Center tank
Right inner tank
Right outer tank

Fuel pump: fuel transfer pumps

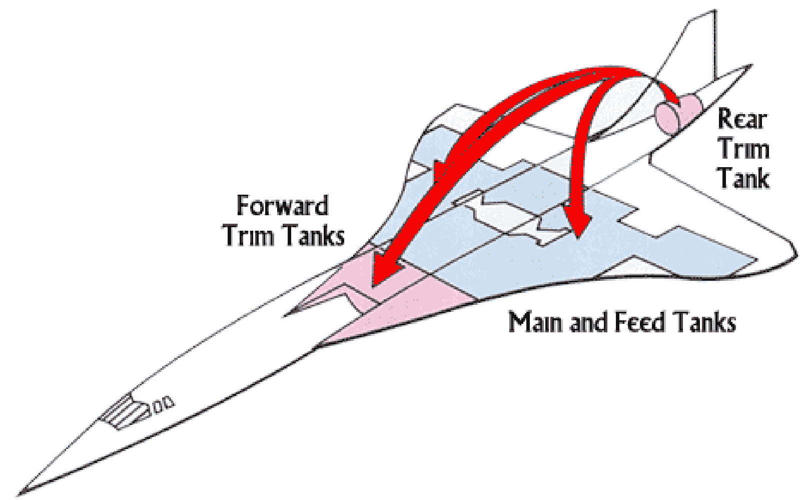
- Fuel transfer pumps are used to transfer fuel between aircraft fuel tanks to ensure the engine fuel feed requirements are satisfied.
- It application scenarios include:
  - Supply fuel to collector tanks
  - Supply fuel to aircraft for pitch trimming
  - Supply fuel to fuselage to maintain centre of gravity



Fuel transfer and trim on Concorde



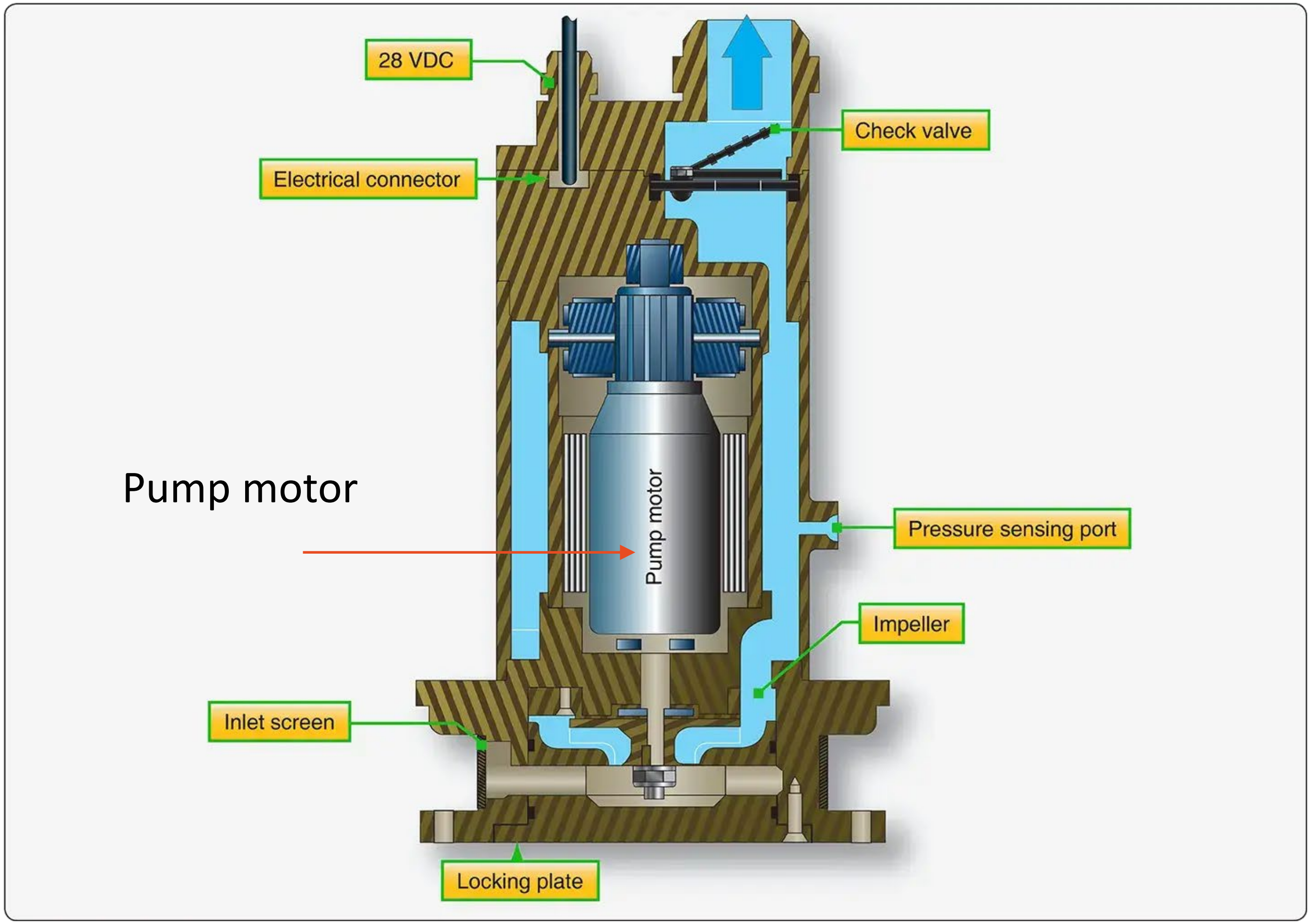
Before takes-off, the flight engineer will start to move fuel from the forward trim tanks to the rear trim and collection tanks during the acceleration through Mach 1 to Mach 2. Around 20 tons of fuel is moved to shift the CG by 2 meters.



As Concorde reaches the end of the cruise and during the deceleration stage, the reverse happens; fuel is pumped forward to the wing transferred forward trim tanks. This moves the CG forward again and the therefore the lift moves forward.

Fuel pump: fuel booster pumps

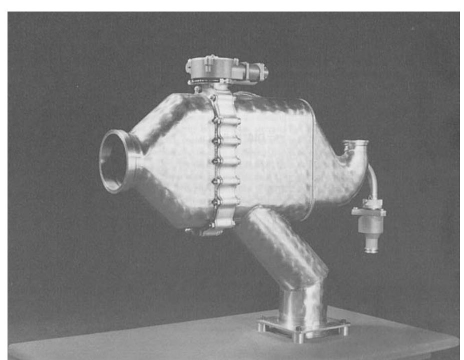
- Fuel booster pumps are also called the engine feed pumps: to booster fuel to the engine
- For large aircraft:
  - electric motor-driven pumps are often used
  - hydraulically driven or ejectors can be also be found.
- The booster pumps are often worked at a higher pressure than the vapour pressure to maintain to avoid cavitation or flame-out.



28 VDC
Check valve
Electrical connector
Pump motor
Pump motor
Pressure sensing port
Impeller
Inlet screen
Locking plate

Fuel valves/閥門

- Fuel valves are used to guide the fuel flow within the aircraft fuel systems. They can be controlled manually or electrically.
- A class of the valves are used to transfer the fuel in the system. Based on the functionality, the valves include:
  - Shut-off valves: to shut-off fuel flow when required
  - Tank selector valve: to select which fuel tank to use
  - Fuel dump valve: to dump excess fuel in emergency
  - Fuel vent valves: to vent the aircraft fuel tanks of air during refuelling
- The check valves (non-return valves) are used restrict the flow to one direction



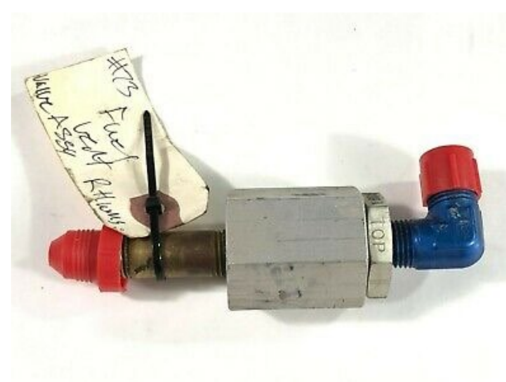
Example of check valve (High Temp Engineers/Cobham)

Fuel valves/閥門

Shut-off valve

selector valve

Fuel dump valve/燃油放泄閥



Fuel vent valves/燃油排氣閥

Fuel vent

- As the fuel is pumped from the tank to other locations, the space should be replaced by air. Therefore, the vent component is necessary.
- Otherwise, vacuum will be created:
  - The fuel flow will be stopped
  - The tank could collapse due to the pressure difference
- Vents must be heated or flush mounted for ice-protection.

Fuel quantity measurement

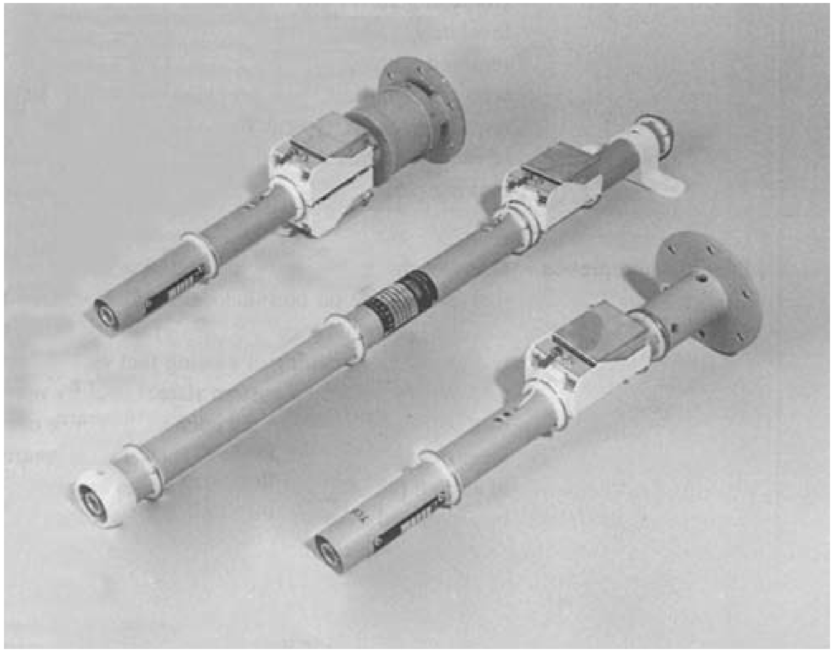
The purpose of the Fuel Quantity Measuring System is to provide the pilot with a visual representation of the amount of useable fuel which is currently being held within the aircrafts fuel tanks. Both of these systems provide fuel quantity information by varying a precisely controlled electrical signal

Fuel quantity measurements

- The difficulties in measuring the fuel on board (FOB) come from:
  - Measuring the fluid level with a body in motion:
    - The inertia of the fluid can cause slosh of the fuel
  - The aircraft fuel tanks have irregular shapes
    - The shapes are irregular, and the boundaries are changed to adapt to the other components to ensure the structure is firmly installed.
    - Multiple sensors will be needed to ensure the redundancy of the system
  - The aircraft fuel has diverse properties with different composition
    - The density of aviation oil varies significantly with temperature
    - Additives are also added to realize the specific functionalities

Fuel quantity measurement probes

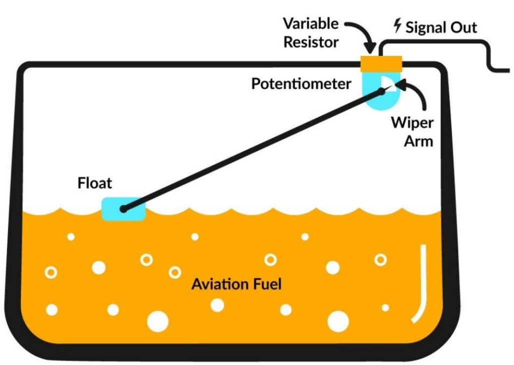
- Common fuel quantity measurement probes are cylindrical tube-shaped with a diameter about 1 inch.
- They are often made of metal due to the reliability and light weight
- The measurement accuracy can be affected by:
  - Tank geometry: requires a optimum number of probes
  - Attitude envelope: affects the distribution of the probes
  - Permittivity variation: Reference units may be used for calibration



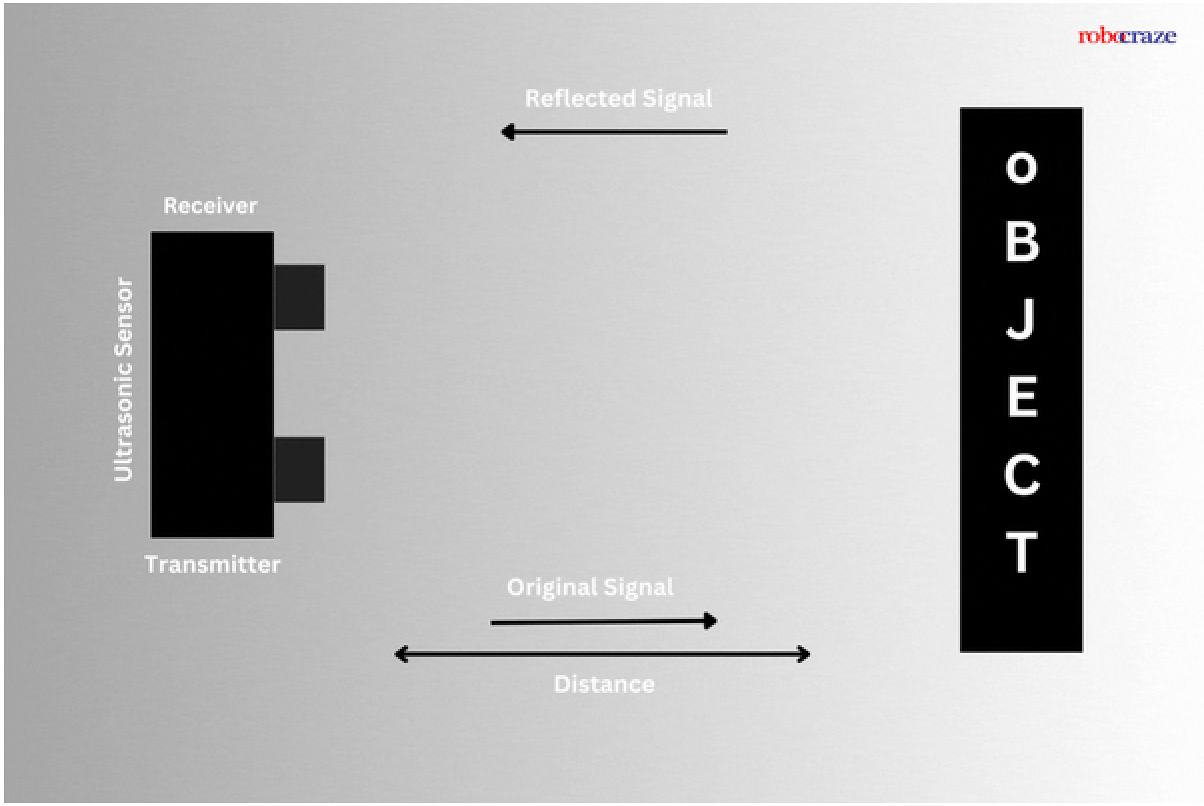
Examples of fuel probe units

Level sensors

- Level sensors measure the fuel level.
  - They are used to prevent the fuel tank from overfill.
  - They are also used for critical low level sensing to ensure the safety.
- Types of fuel level sensors:
  - Float type: similar to domestic toilet
  - Solid type (Zener diode): accurate and fast response
  - Ultrasonic sensors: become favoured



Resistive System

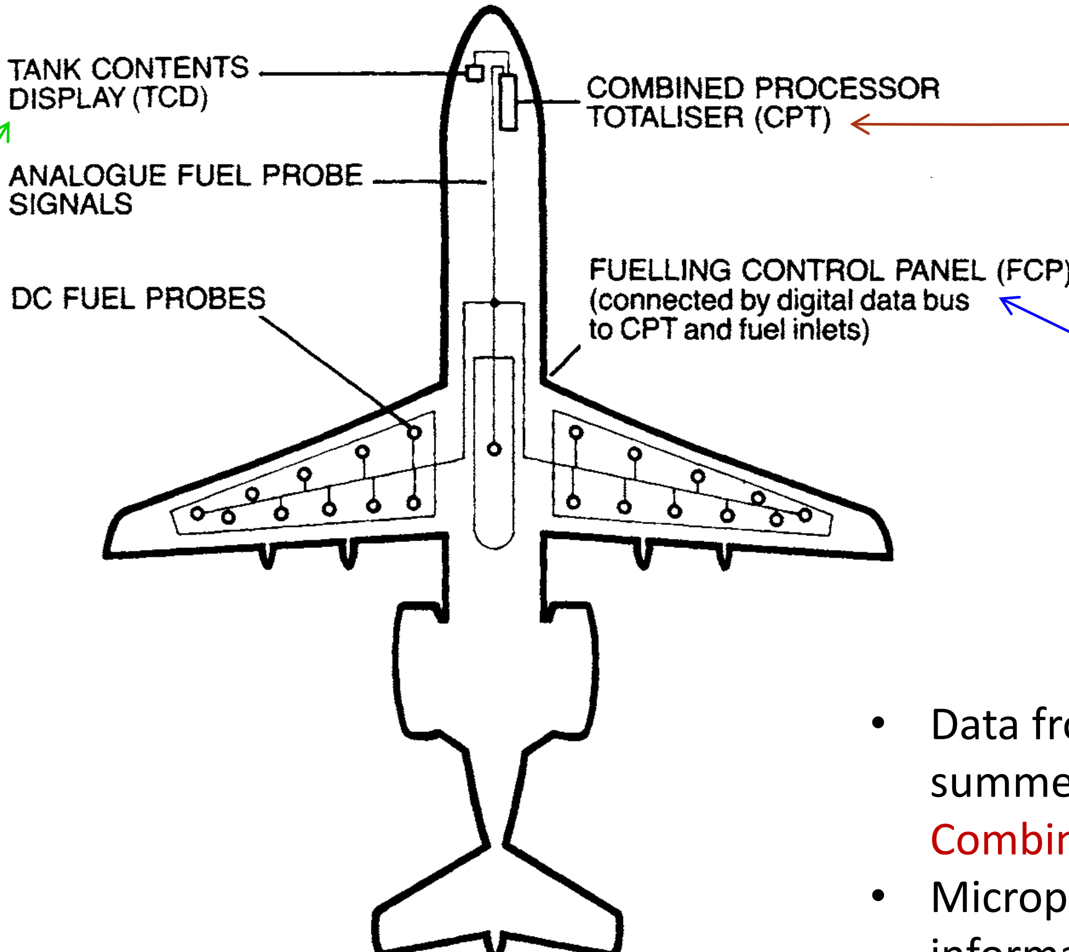


Distance = Time * speed of sound / 2

Fuel quantity measurement systems

- Depending on the associated signalling technique, the fuel measurement probes can be used in:
  - AC system: the tank information is conveyed by AC voltage.
    - Advantages: lighter, cheaper and more reliable
    - Disadvantages: might be suffer from the EMI (electro-magnetic interference)
  - DC system: the probes are fed by constant voltage/frequency probe drives and the fuel information was given by DC analogue signal
    - Advantages: it tends to be smaller and the reliability is increased
    - However, DC system requires additional components within the tank
- Choice between AC and DC systems are heavily dependent on the airframe manufacturer.

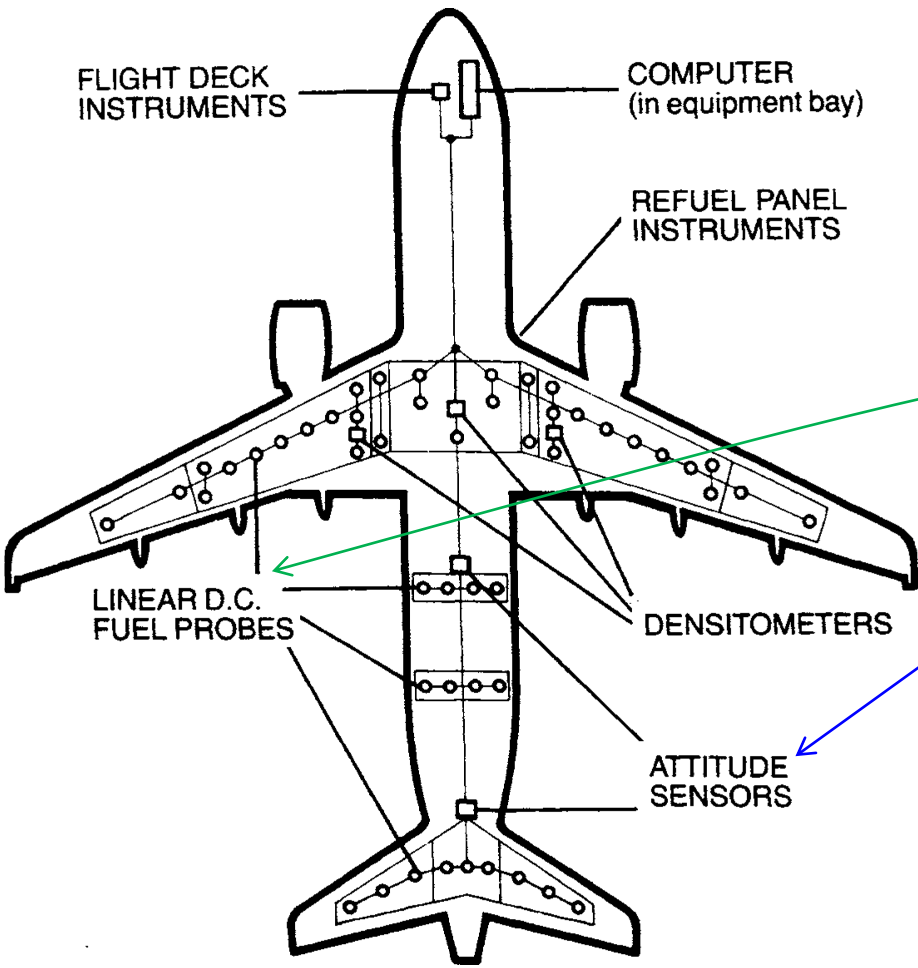
Fuel quantity measurement systems



Fokker 100 diagrammatic layout

- Data from the fuel probes are summed and conditioned in the Combined Processor Totalizer (CPT)
- Microprocessors process the information and display it on the TCD and FCP

Fuel quantity measurement systems



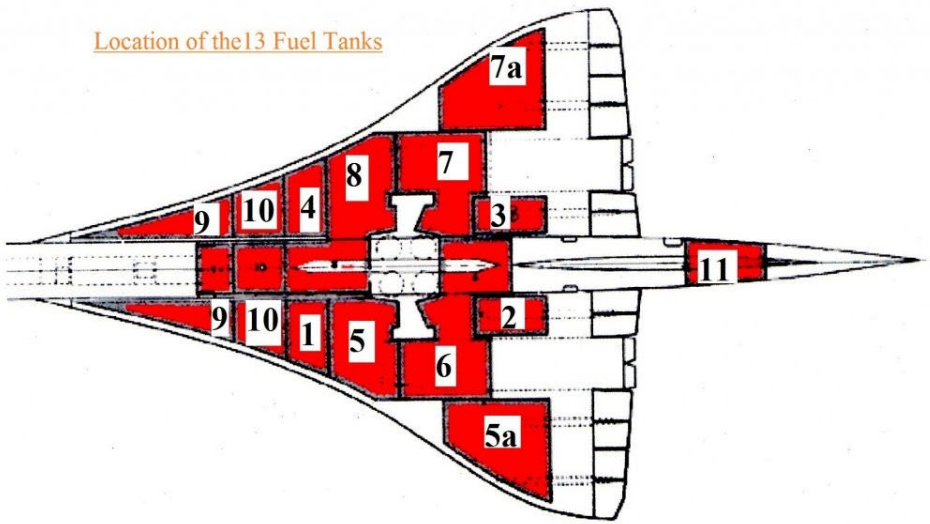
Airbus diagrammatic layout

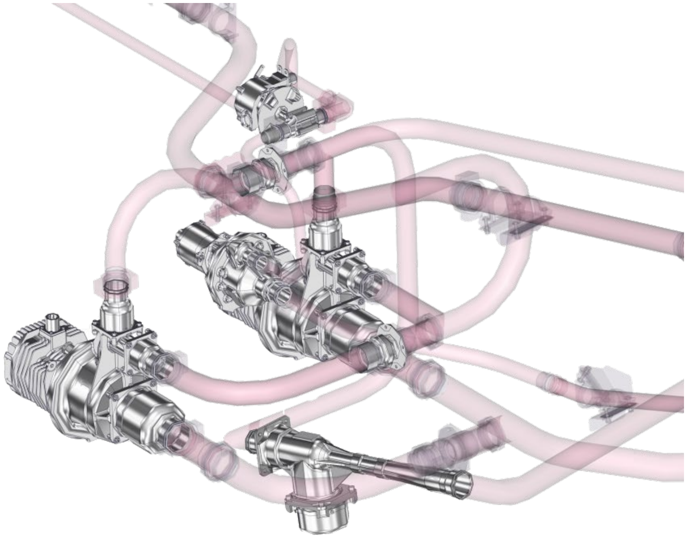
- Linear DC probes are located in the wing tanks and fuselage tanks
- Attitude data are also used
- The fuel tank geometry and the computed density, permittivity, fuel temperature, attitude, etc., are displayed.

Fuel system operation modes

Fuel system operation modes

- For practical aircraft operation, the fuel system is worked in combination with other systems, notably structure and engine
- The arrangement of multiple tanks increases the complexity of the interconnecting pipes:
  - The fuselage tanks often have more complex geometries than wing tanks





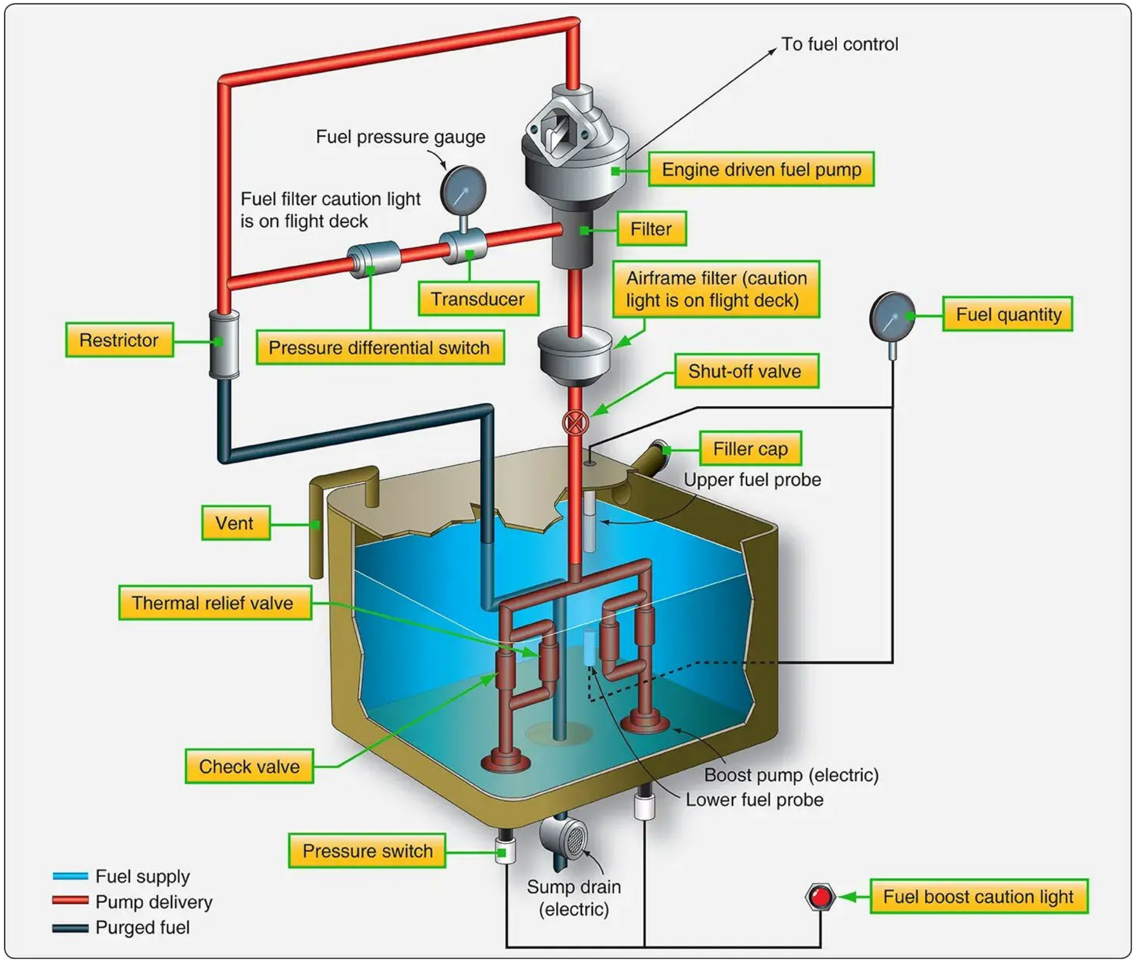
Fuel system operation modes

- Typical fuel system operation modes include:
  - Pressurization
  - Engine feed
  - Fuel transfer
  - Refuel/defuel
  - Venting
  - Use fuel as heat sink
  - External fuel tanks
  - Fuel jettison
  - In-flight fuelling, etc.

Some of the operation modes may not be exhibited in some specific fuel systems, depending of the aircraft and mission.

Fuel system operation mode: pressurization/加壓

- Pressurization is to force the fuel at relatively low pressure to other locations:
  - It might be unnecessary for some aircraft as gravity might be sufficient for this purpose
- The high-pressure air used for pressurization can be provided by the air from the engine bleed system.
  - Pressure reducing valves (PRVs) are often used to ensure the pressure is at an acceptable level.
- Some aircraft, e.g., F-22, may use the inert gas (惰性氣體) to pressure the fuel tanks, which is provided by the On-Board Inert Gas Generating Systems (OBIGGS).

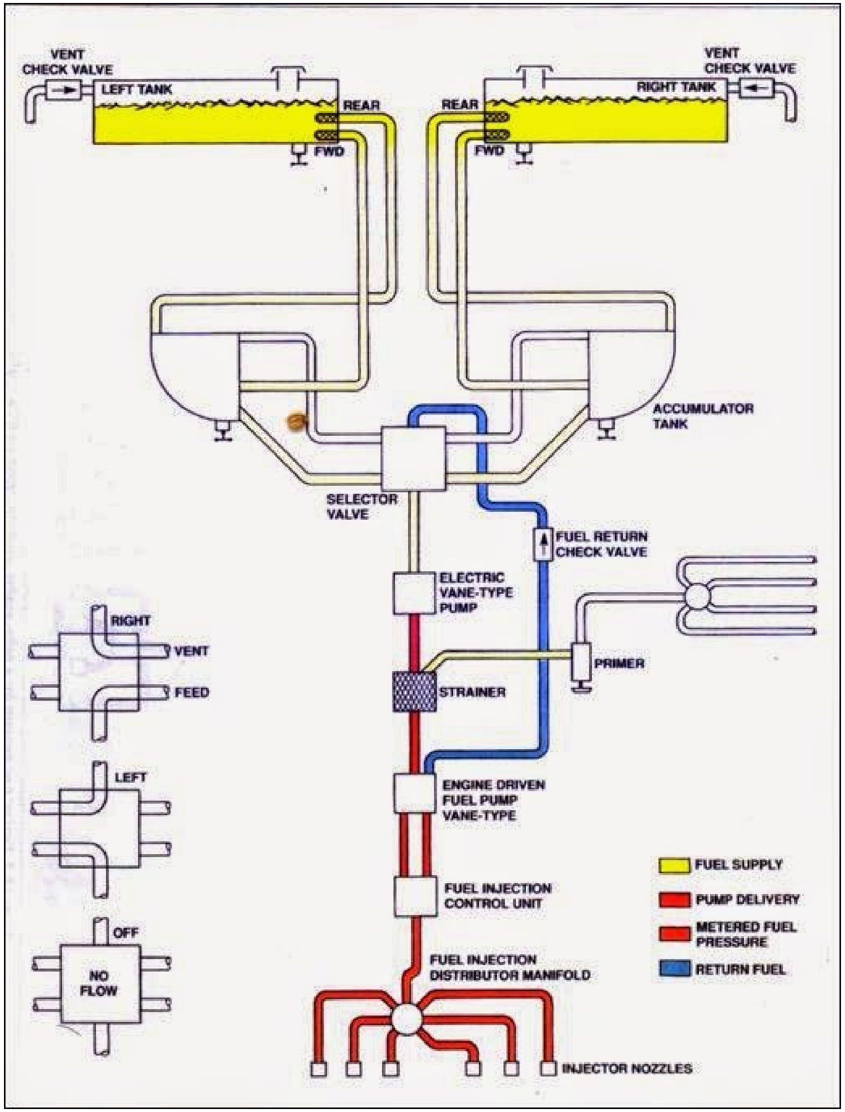


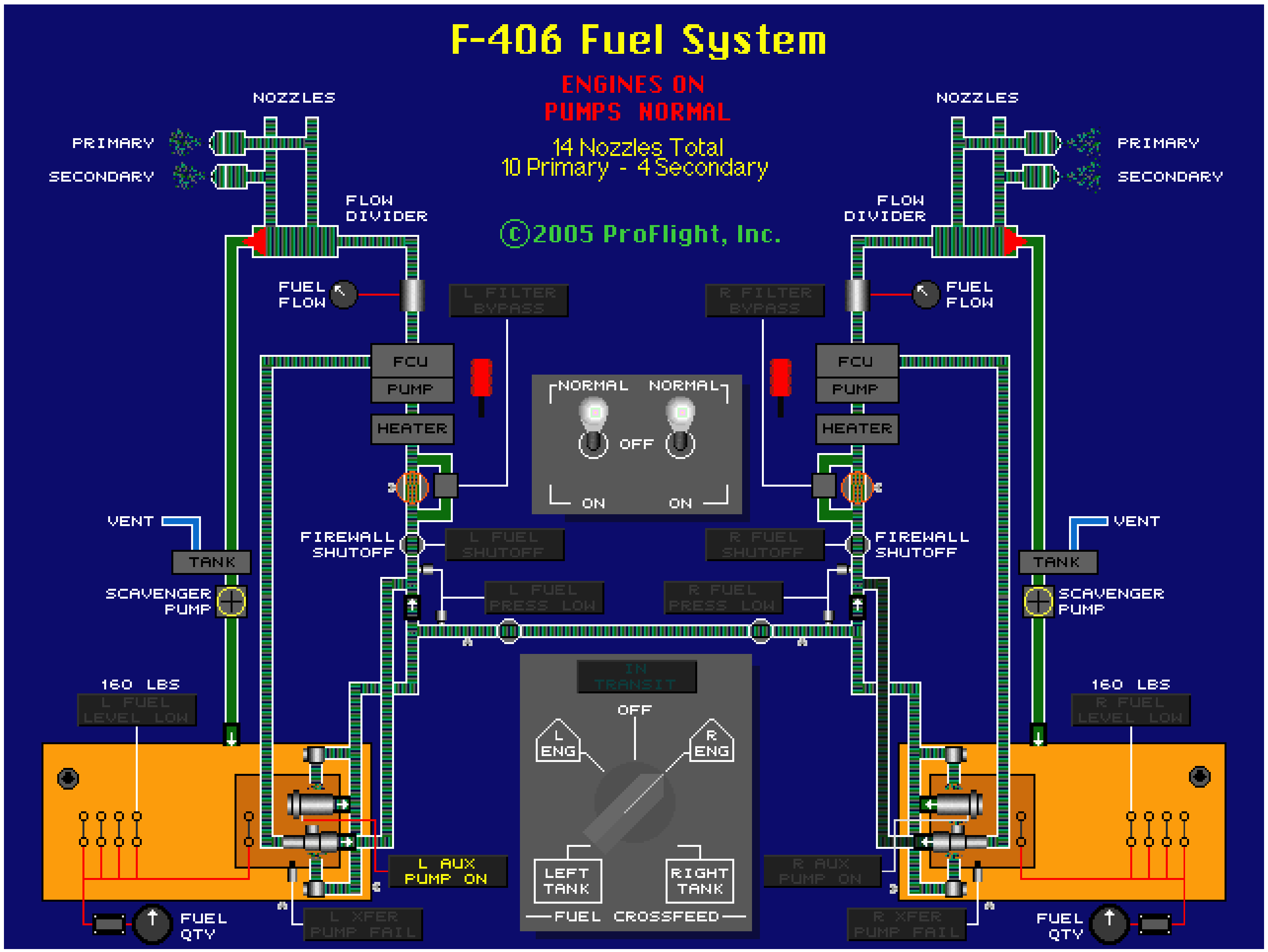
- Here the pressurization refers to the modulation of the pressure in the fuel.
- We will introduce the concept of cabin pressurization weeks later.

Fuel system operation mode: engine feed

- Engine feed refers to the supply of fuel to the engines: most critical element of the fuel system.
- The fuel is collected before sent to be engine feed line.
  - The collector tanks hold sufficient fuel for several minutes, and the fuel contents are measured using multiple probes.
  - The booster pumps pressurize the fuel flow to the engines. The pumps are often driven by 115V AC motors (to be described in Electrical System session).
  - Then, the high-pressure (HP) pumps, driven by engine accessory gearbox, to supply the fuel to the engine fuel control systems
  - Shut-off valves are associated with the fuel control.

A fuel line is a pipe used to transfer fuel from one point in a vehicle to another.


VENT
CHECK VALVE
LEFT TANK
REAR
FWD
VENT
CHECK VALVE
RIGHT TANK
REAR
FWD
ACCUMULATOR
TANK
SELECTOR
VALVE
FUEL RETURN
CHECK VALVE
ELECTRIC
VANE-TYPE
PUMP
PRIMER
STRAINER
RIGHT
VENT
FEED
LEFT
OFF
NO
FLOW
ENGINE DRIVEN
FUEL PUMP
VANE-TYPE
FUEL INJECTION
CONTROL UNIT
FUEL INJECTION
DISTRIBUTOR MANIFOLD
INJECTOR NOZZLES
FUEL SUPPLY
PUMP DELIVERY
METERED FUEL
PRESSURE
RETURN FUEL


F-406 Fuel System
ENGINES ON
PUMPS NORMAL
14 Nozzles Total
10 Primary - 4 Secondary
©2005 ProFlight, Inc.
NOZZLES
PRIMARY
SECONDARY
FLOW DIVIDER
FUEL FLOW
L FILTER BYPASS
R FILTER BYPASS
FCU
PUMP
HEATER
NORMAL
OFF
ON
VENT
TANK
SCAVENGER PUMP
FIREWALL SHUTOFF
L FUEL SHUTOFF
R FUEL SHUTOFF
L FUEL PRESS LOW
R FUEL PRESS LOW
160 LBS
L FUEL LEVEL LOW
R FUEL LEVEL LOW
IN TRANSIT
L ENG
R ENG
LEFT TANK
RIGHT TANK
FUEL CROSSFEED
L AUX PUMP ON
R AUX PUMP ON
L XFER PUMP FAIL
R XFER PUMP FAIL
FUEL QTY

Fuel system operation mode: fuel transfer

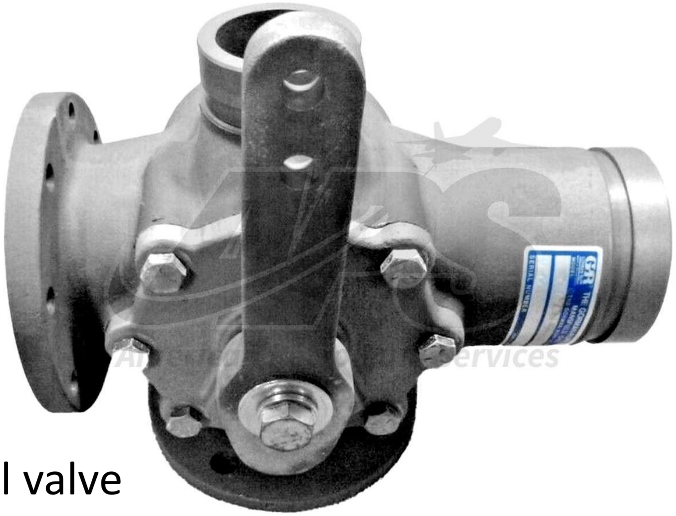
- Fuel transfer is to move fuel from main wing and fuselage tanks to the collector tank
  - Note: For commercial aircraft, there is a tend to use fewer tanks with regular shapes to reduce the needs of fuel transfer pumps
- Fuel transfer pumps are activated by the fuel levels in the tanks.
  - If the fuel level of the collector tank is lower than a critical level, the transfer pumps will work automatically.
- Sometimes, the fuel transfer is used to adjust the centre of gravity (CG) of the aircraft.
  - Examples are the Eurofighter Typhoon and F-35.

Eurofighter Typhoon

F35

Fuel system operation mode: Refuel/defuel

- The refuel and refuel processes are controlled by a separated subsystem.
  - A **refuelling receptacle**(加油插座) is connected to the refuelling tanker, and fuels are charged and distributed to various aircraft tanks.
  - In the crudest case the fuel will enter the tanks till full, and the refuelling valve will shut off to stop fuelling any more.
- Defueling is just almost the reverse processes: mainly for maintenance purposes



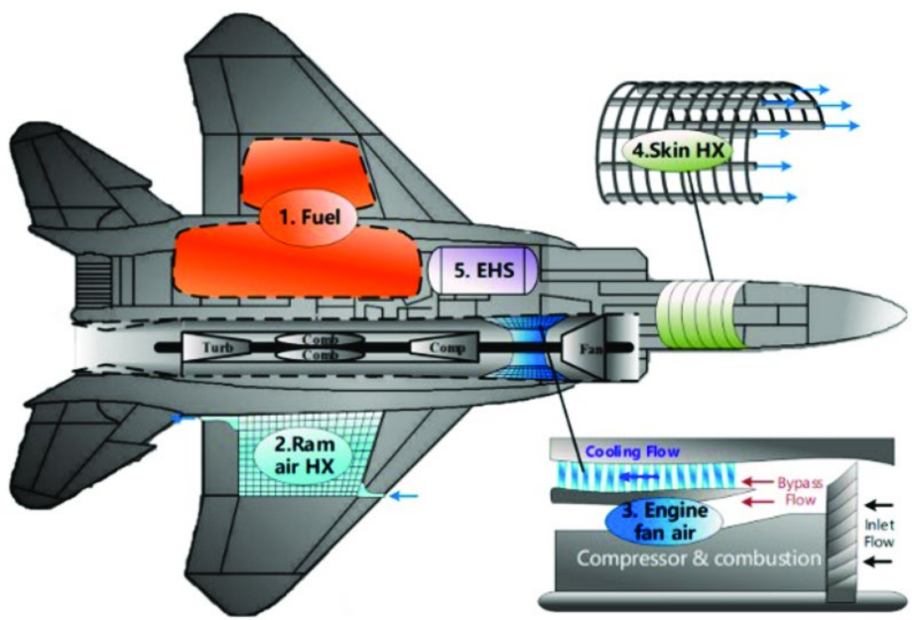
Fuel-defuel valve

Fuel system operation mode: venting

- The need of venting in aircraft fuel system has be mentioned before.
- Venting is also needed in other fuel system operation modes:
  - During the refuel process, spillage of fuel to the outside should be avoided, a vent box (surge tank) is used to capture the fuel that may enter the vent line
  - In military aircraft at high altitude, the vent system is also needed to prevent the vaporization or boiling

Fuel system operation mode: heat sink

- For some high-performance aircraft, e.g., jet fighters, large amount of heat could be generated
  - The heat can be generated from the hydraulic and environmental control systems
- The fuel system can act as a heat sink to absorb these heat



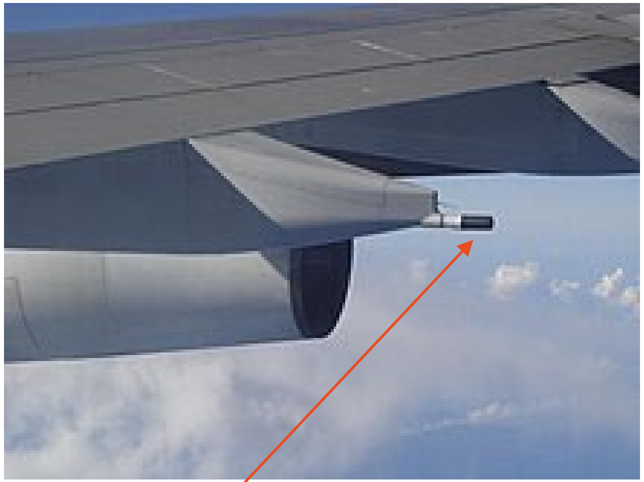
Examples of the heat sinks in a modern aircraft:
- EHS: electric heater system
- HX: heat exchanger

Sources: Mao, et al., Entropy, 21(3), 223, 2019

Fuel system operation mode: fuel dumping/燃油抛弃

- It is also called fuel jettison: a procedure used by aircraft in certain emergency situation before returning to the airport shorting.
  - If the airplane is landing at the maximum take-off mass, it may cause structural damage or break apart.
  - The purpose of fuel dumping is to reduce the aircraft's weight

Fuel dumping of an Airbus A340-600 above the Atlantic Ocean near Nova Scotia



Fuel dump nozzle of an Airbus A340-300

Fuel system operation mode: fuel dumping/燃油抛弃

- Dump-and-burn: the drum fuel is ignited using the aircraft's afterburner.
- It is also referred to "torching" or "zippos".
- Sometimes, it is also used in air shows.

F-111 fuel dump and burn in Williamtown Airshow 2010

Summary

Summary

- Characteristics of the fuel systems is introduced
- Major components of the fuel systems are introduced
- How to measure and manage the fuel quantity?
- What are the typical operation modes of the fuel system?