Fuel System

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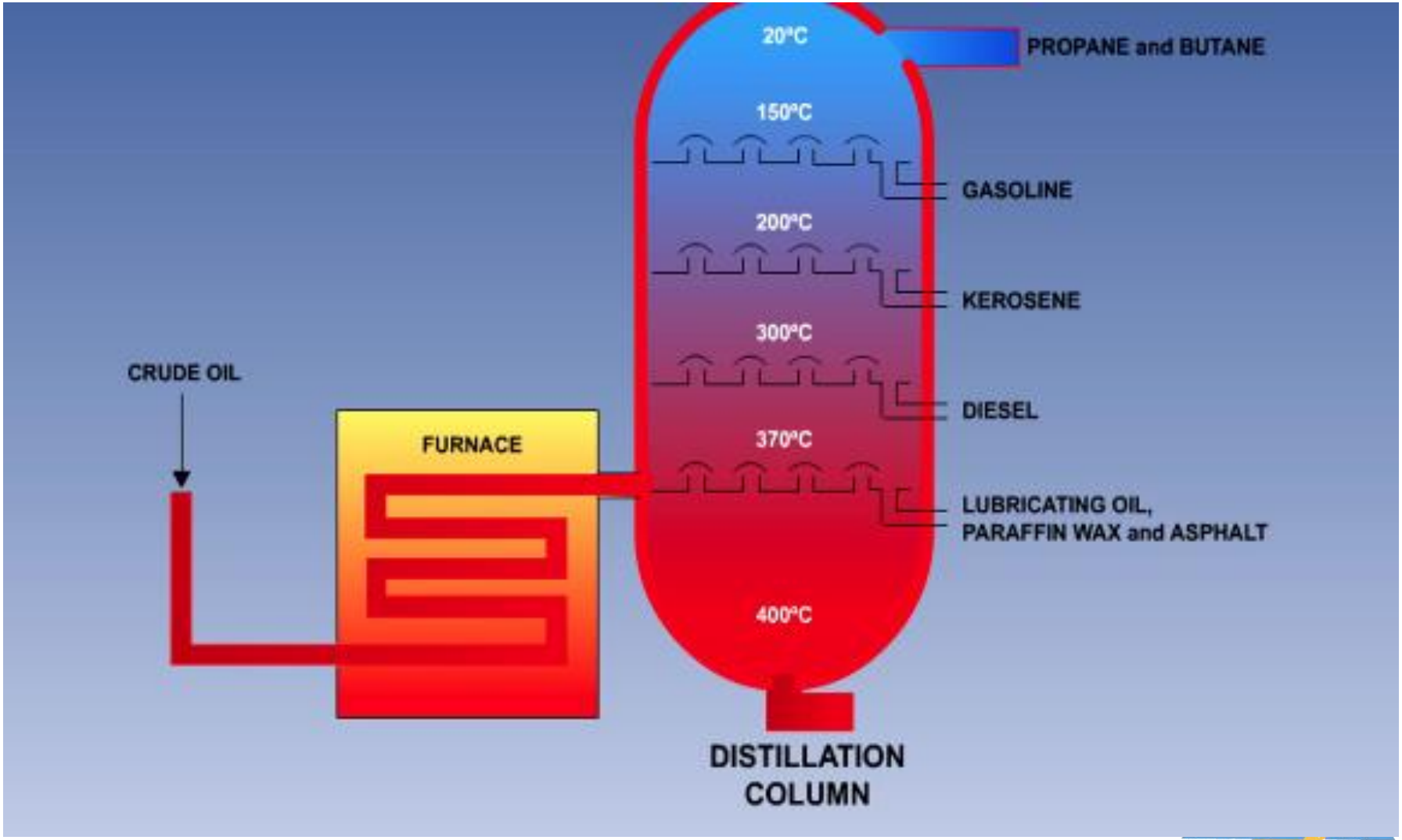
Fuel System

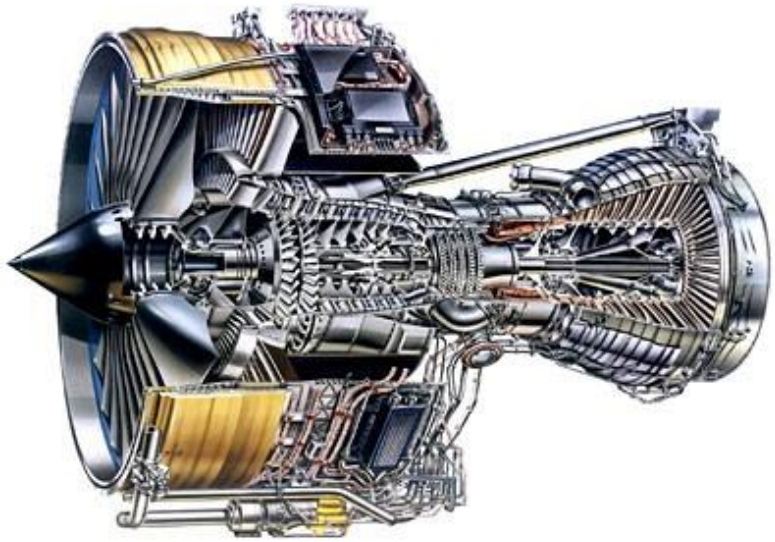
Types of Fuel

Civilian	**Military**
Jet A	JP-4
Jet A-1	JP-5
Jet B	JP-8


20°C
PROPANE and BUTANE
150°C
GASOLINE
200°C
KEROSENE
300°C
DIESEL
370°C
LUBRICATING OIL,
PARAFFIN WAX and ASPHALT
400°C
CRUDE OIL
FURNACE
DISTILLATION
COLUMN

Basic Properties of Fuel

Ideal Fuel Specifications



- Flow easily
- High calorific value
- Non-corrosive
- Low fire hazard
- Ease of engine starting
- Good lubricating qualities
- Complete combustion under all conditions
- No damage to the engine from combustion by-products

Basic Properties of Fuel

- Volatile – Tendency to change from liquid to vapour
- Vapour Pressure – Pressure at which fuel vaporizes Flash Point – Lowest temperature at which there is sufficient vapours above the liquid to ignite without sustaining a flame
- Fire Point – Lowest temperature at which the fuel can sustain combustion through vaporisation
- Auto-Ignition Temperature – Temperature at which fuel spontaneously ignites without the presence of the source
- Freezing Point – Point at which ice crystals disappears when it warms up

Vapor Lock

- Vapor lock is a condition in which AVGAS vaporizes in the fuel line or other components between the fuel tank and the carburetor.
- This typically occurs on warm days on aircraft with engine-driven fuel pumps that suck fuel from the tank(s).
- Vapor lock can be caused by excessively hot fuel, low pressure, or excessive turbulence of the fuel traveling through the fuel system.
- In each case, liquid fuel vaporizes prematurely and blocks the flow of liquid fuel to the carburetor.
- Fuel may vaporize before it reaches the carburetor, especially if it is drawn up a line under a low pressure, or if it swirls while navigating a sharp bend in the tubing.

Vapor Lock

- To make matters worse, when an aircraft climbs rapidly, the pressure on the fuel in the tank decreases while the fuel is still warm.
- This causes an increase in fuel vaporization that can also lead to vapor lock.
- Various steps can be taken to prevent vapor lock. The use of boost pumps located in the fuel tank that force pressurized liquid fuel to the engine is most common.

Fuel System

- Aviation gasoline is rated by octane rating
- Octane rating of a fuel is the measure of the fuel resistance to detonation when subjected to high temperature and pressure

High Compression Engine Requires 100 Octane Fuel

Low Compression Engine Uses 80 Octane Fuel

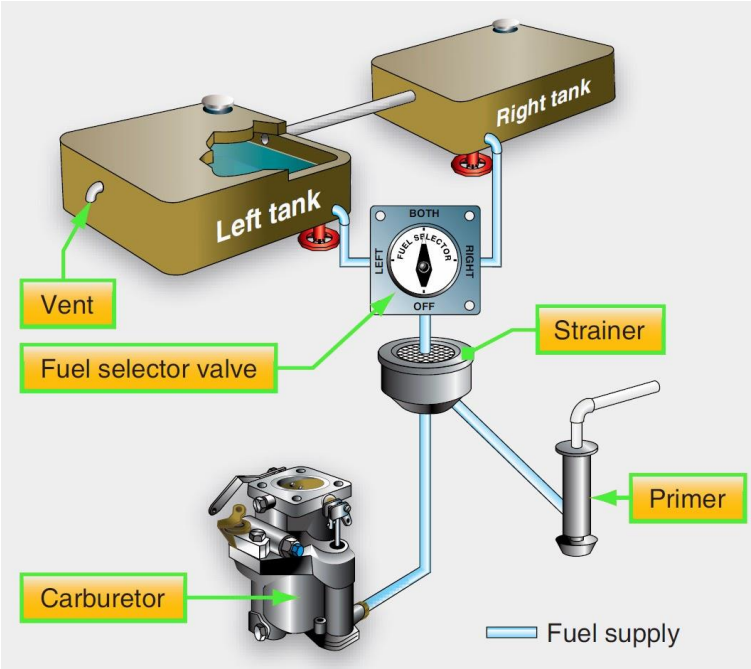
Fuel Feed System

Main Tanks

- Header Tank (separate from main tanks, hold enough fuel for engines to run during complicated maneuvers)
- Gravity Feed (Small Aircraft Only)
- Electric/Engine – driven fuel pumps

Gravity Feed Systems

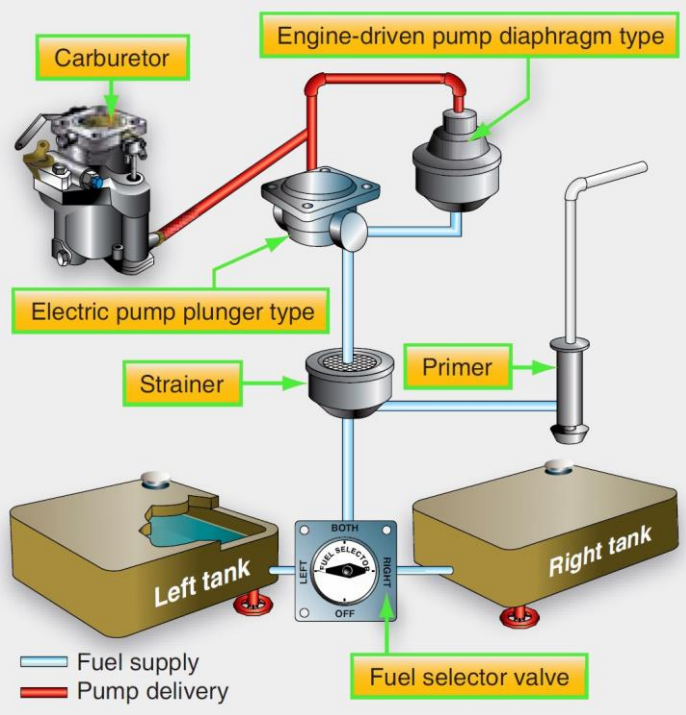
- High-wing aircraft with a fuel tank in each wing are common.
- With the tanks above the engine, gravity is used to deliver the fuel.
- The space above the liquid fuel is vented to maintain atmospheric pressure on the fuel as the tank empties.
- The two tanks are also vented to each other to ensure equal pressure when both tanks feed the engine.
- A single screened outlet on each tank feeds lines that connect to either a fuel shutoff valve or multiposition selector valve.
- The shutoff valve has two positions: fuel ON and fuel OFF.
- If installed, the selector valve provides four options: fuel shutoff to the engine; fuel feed from the right wing tank only; fuel feed from the left fuel tank only; fuel feed to the engine from both tanks simultaneously.



The gravity-feed fuel system in a single-engine high wing aircraft is the simplest aircraft fuel system

Pump Feed Systems

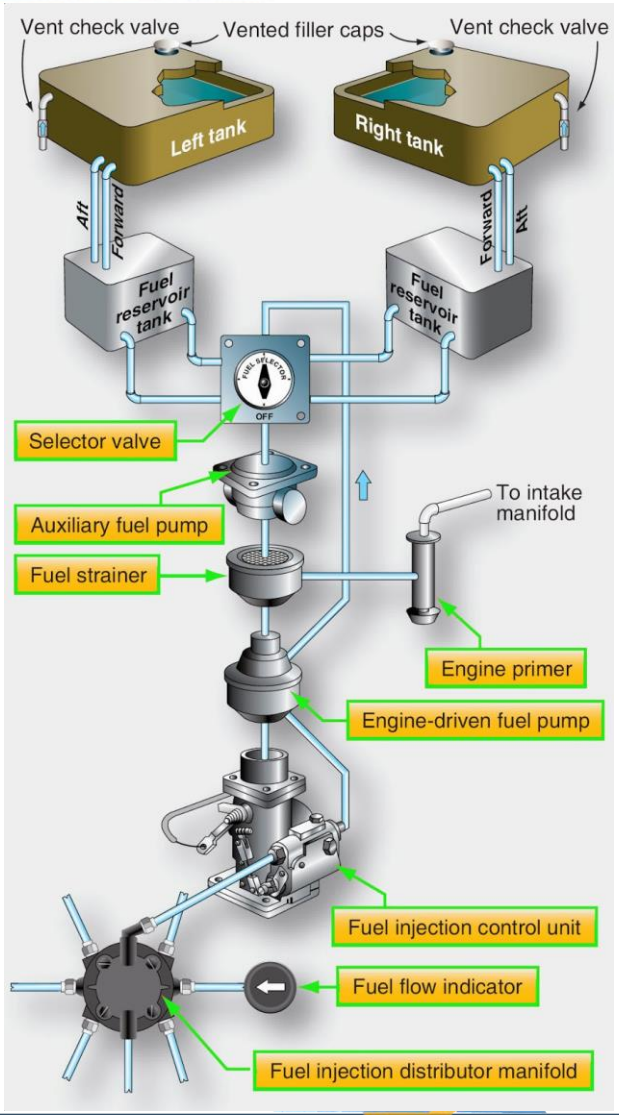
- Low- and mid-wing single reciprocating engine aircraft cannot utilize gravity-feed fuel systems because the fuel tanks are not located above the engine.
- Instead, one or more pumps are used to move the fuel from the tanks to the engine.
- Each tank has a line from the screened outlet to a selector valve.
- However, fuel cannot be drawn from both tanks simultaneously; if the fuel is depleted in one tank, the pump would draw air from that tank instead of fuel from the full tank.
- Since fuel is not drawn from both tanks at the same time, there is no need to connect the tank vent spaces together.
- The electric pump also supplies fuel pressure while starting and is used to prevent vapor lock during flight at high altitude.



A single reciprocating engine aircraft with fuel tanks located in wings below the engine uses pumps to draw fuel from the tanks and deliver it to the engine.

High- Wing Aircraft With Fuel Injection System

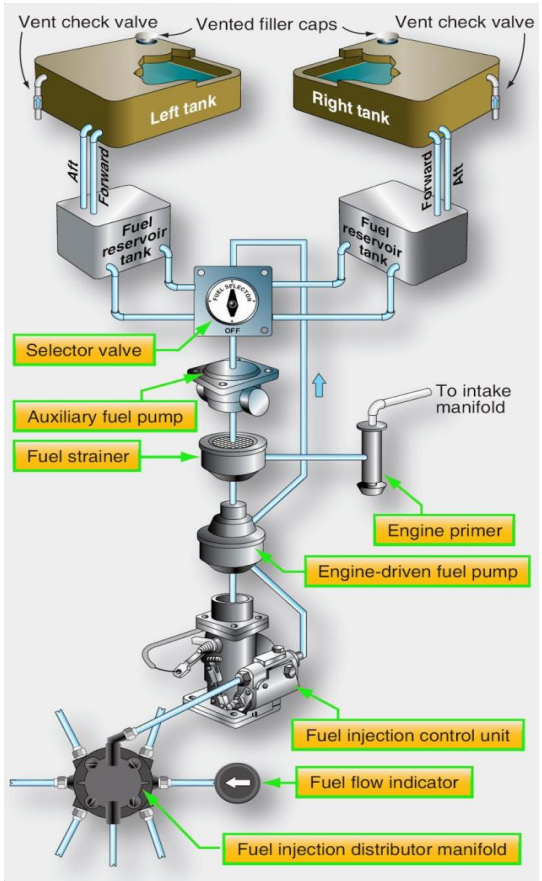
- Some high-wing, high-performance, single-engine general aviation aircraft are equipped with a fuel system that features fuel injection rather than a carburetor.
- It combines gravity flow with the use of a fuel pump(s). The Teledyne-Continental system is an example.
- An electric auxiliary fuel pump draws fuel through the selector valve.
- It forces the fuel through the strainer, making it available for the primer pump and the engine-driven fuel pump.
- This pump is typically used for starting and as a backup should the engine-driven pump fail.
- It is controlled by a switch in the cockpit and does not need to be operating to allow the engine-driven fuel pump access to the fuel.



High- Wing Aircraft With Fuel Injection System

- The engine-driven fuel pump intakes the pressurized fuel from the electrically driven pump or from the reservoir tanks if the electric pump is not operating.
- It supplies a higher-than needed volume of fuel under pressure to the fuel control.
- Excess fuel is returned to the pump, which pumps it through the selector valve into the appropriate reservoir tank.
- Fuel vapor is also returned to tanks by the pump.
- The fuel control unit meters the fuel according to engine rpm and mixture control inputs from the cockpit.

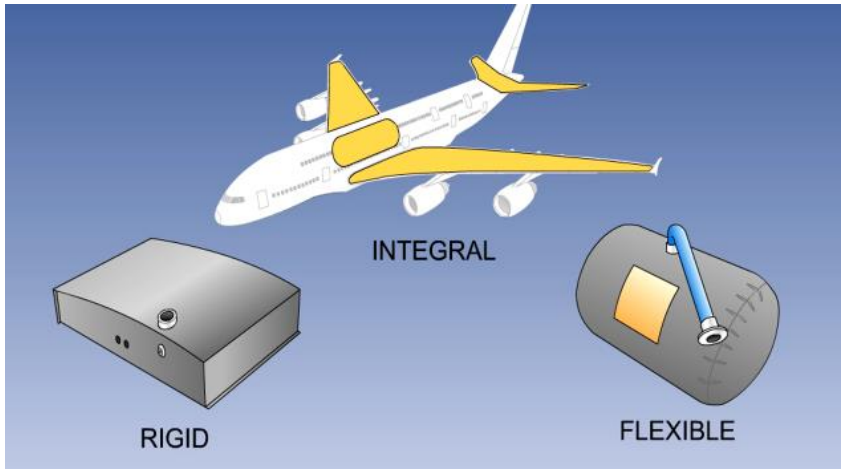
NOTE: Fuel injection systems spray pressurized fuel into the engine intake or directly into the cylinders. Fuel without any air mixed in is required to provide a measured, continuous spray and smooth engine operation.



A Teledyne-Continental fuel system featuring fuel injection used on high-wing, high-performance single-engine aircraft

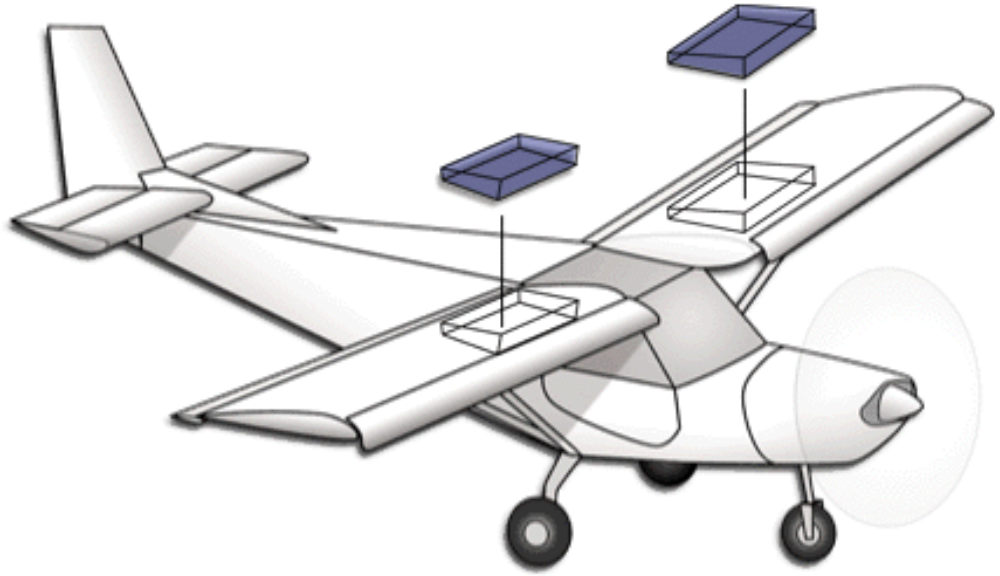
Fuel Tank

- **Types:**
  - Rigid Removable
  - Bladder
  - Integral



- **Rigid Removable Fuel Tank**
  - Separate units that can be completely removed from the aircraft
  - Usually welded or riveted
    - Older ones are soldered

Fuel Tanks



- Rigid removal fuel tanks are often made of aluminum component that are welded together.
- Their tanks are installed in compartment specifically made for the tanks.
- The tank may be held in place with padded straps.
- This types of tank is often found on more expensive light aircraft.

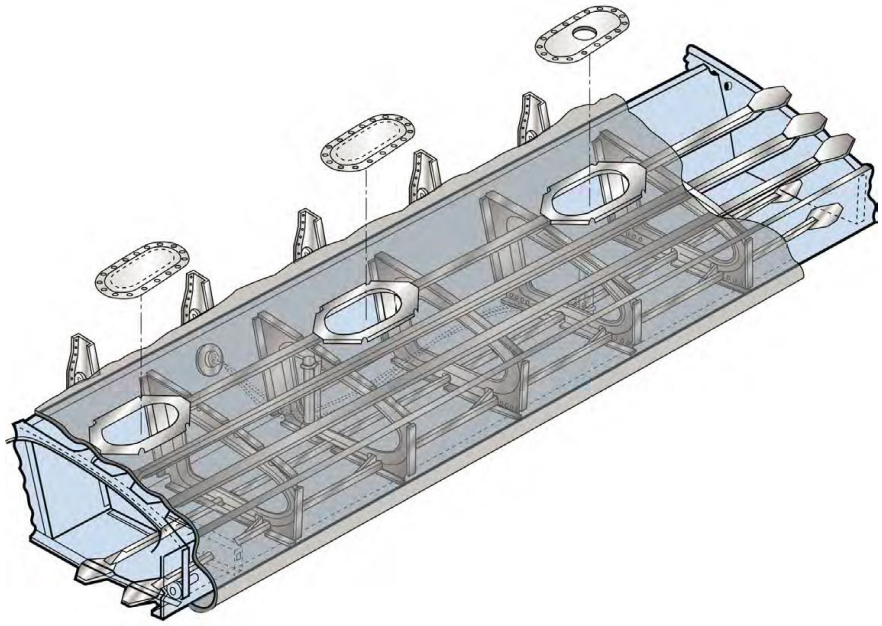
Fuel Tanks

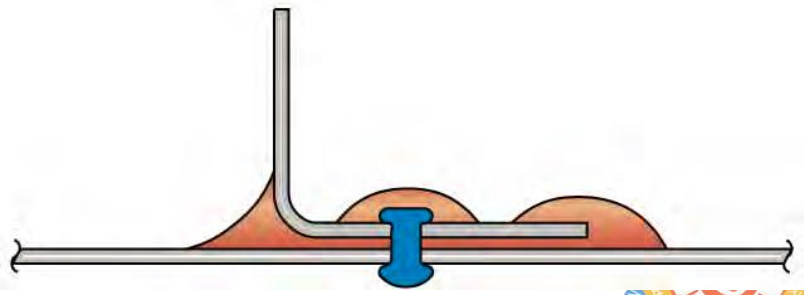
- **Bladder Fuel Tanks**
  - Flexible fuel “Bags”
  - Can be patched
  - Must be installed flat and without wrinkles
  - Must be kept wet
    - If fuel is drained, coat the inside with engine oil

New ATL FueLocker 500 gallon (2000 liter) Collapsible Fuel Tank

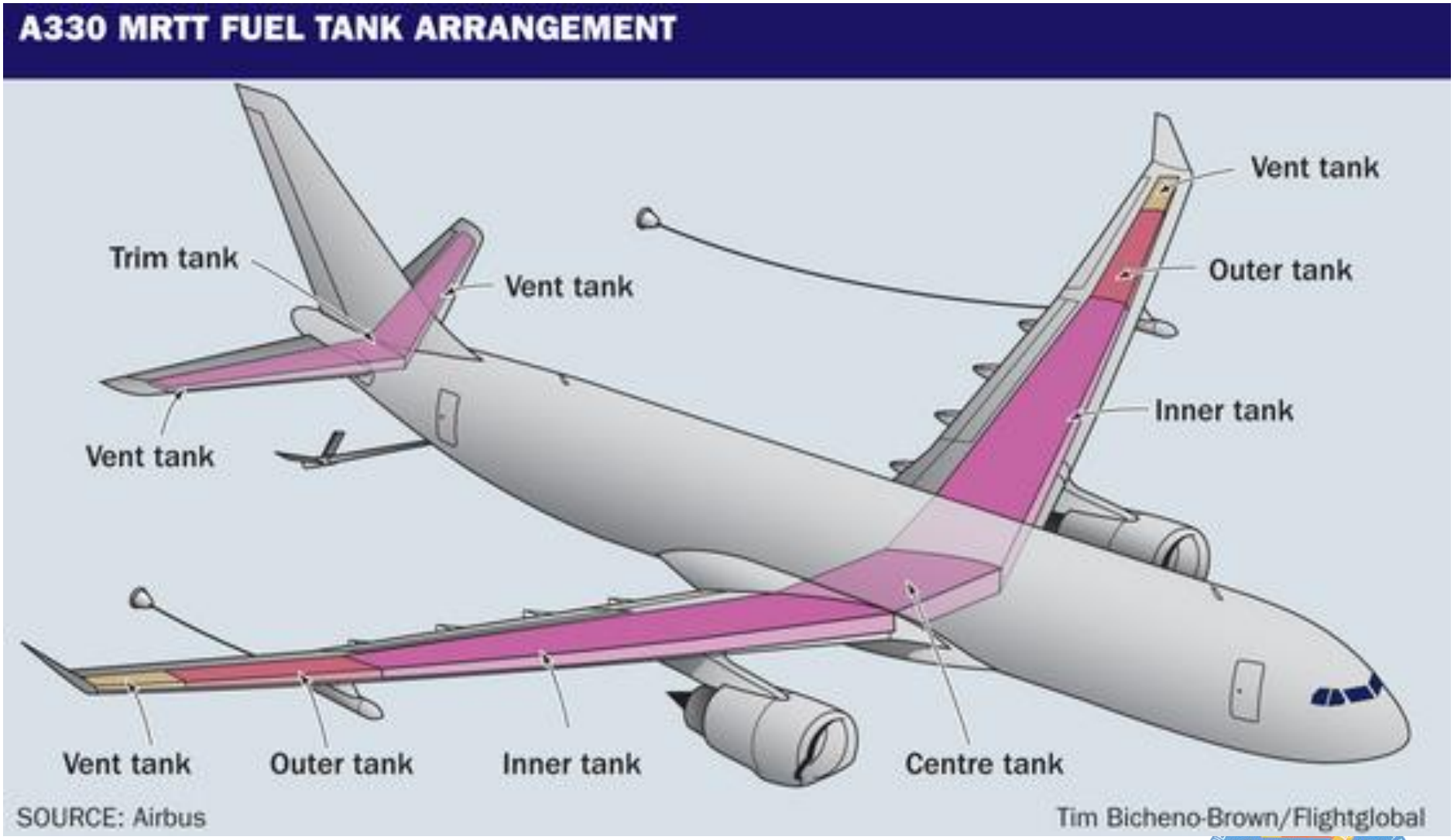
Fuel Tanks

- **Integral Fuel Tank**
  - Parts of the structure of the wings or fuselage are sealed with a fuel resistant sealant to from a fuel tank
  - “Wet Wing”
  - Lightest way to store fuel



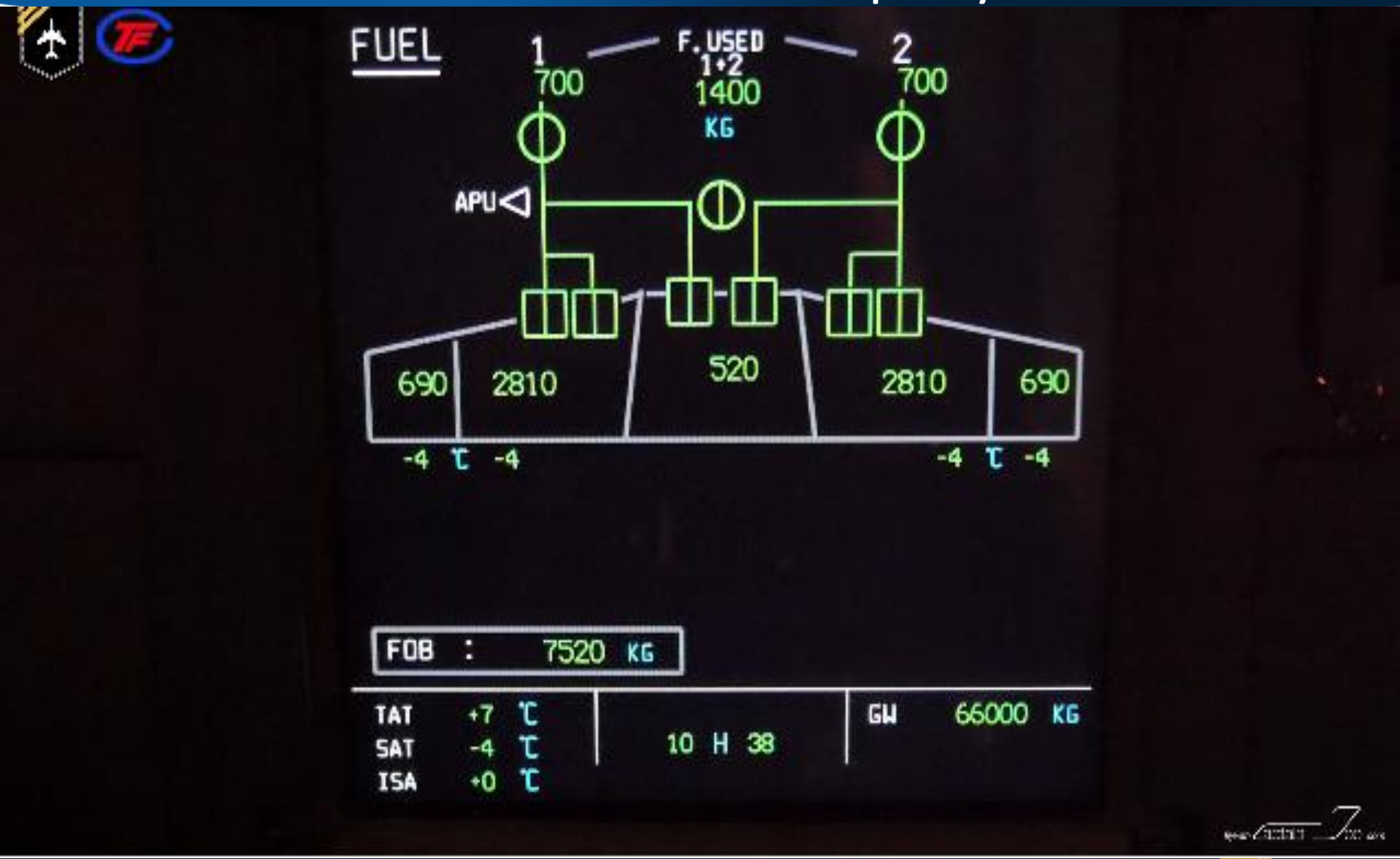


Fuel Tanks

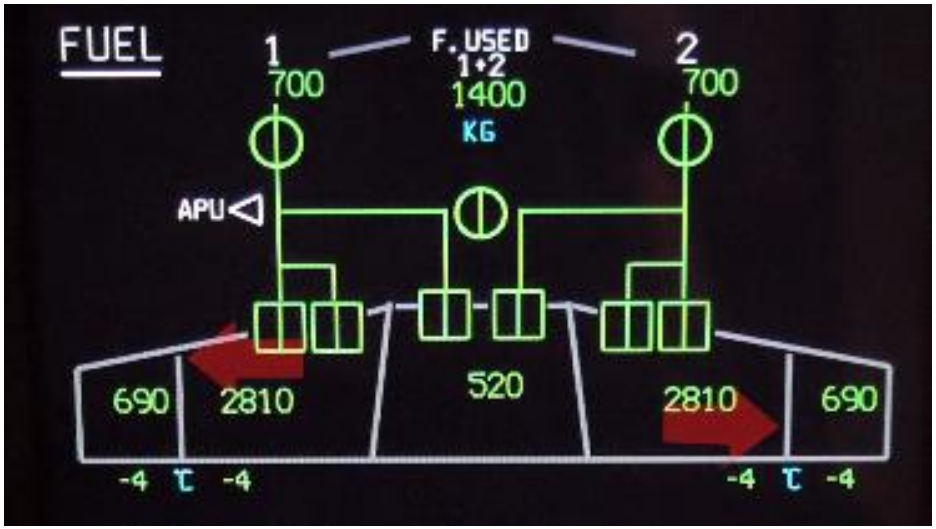

A330 MRTT FUEL TANK ARRANGEMENT
Trim tank
Vent tank
Vent tank
Vent tank
Outer tank
Inner tank
Vent tank
Outer tank
Inner tank
Centre tank
SOURCE: Airbus
Tim Bicheno-Brown/Flightglobal

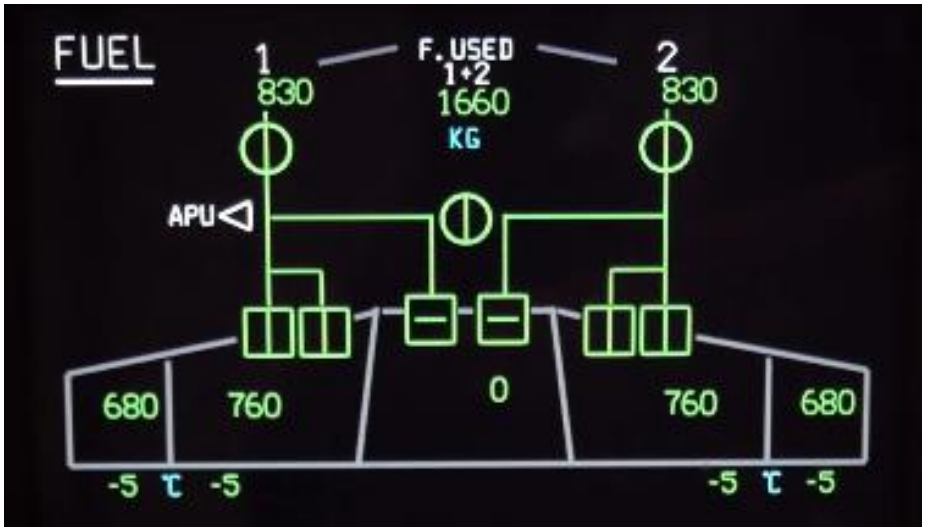
A320

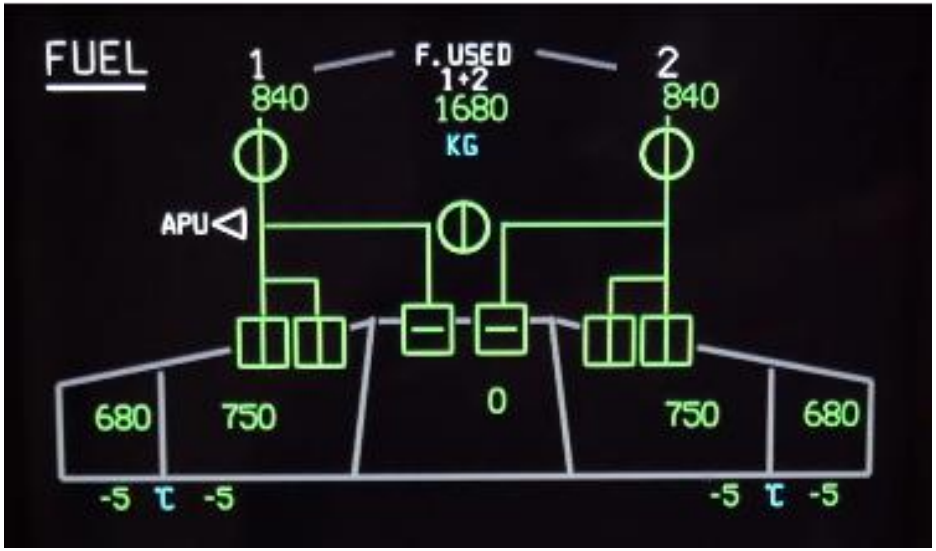
Ecam Fuel Display

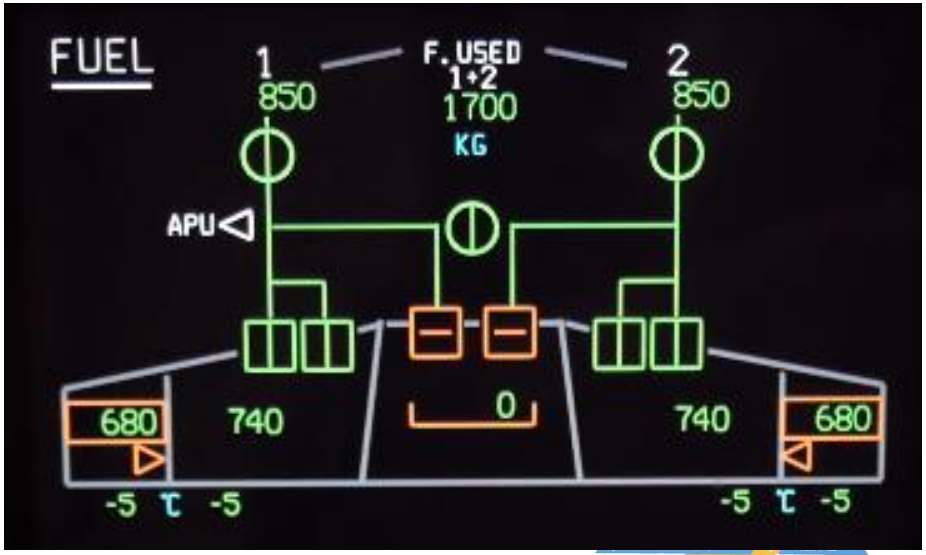


Ecam Fuel Display

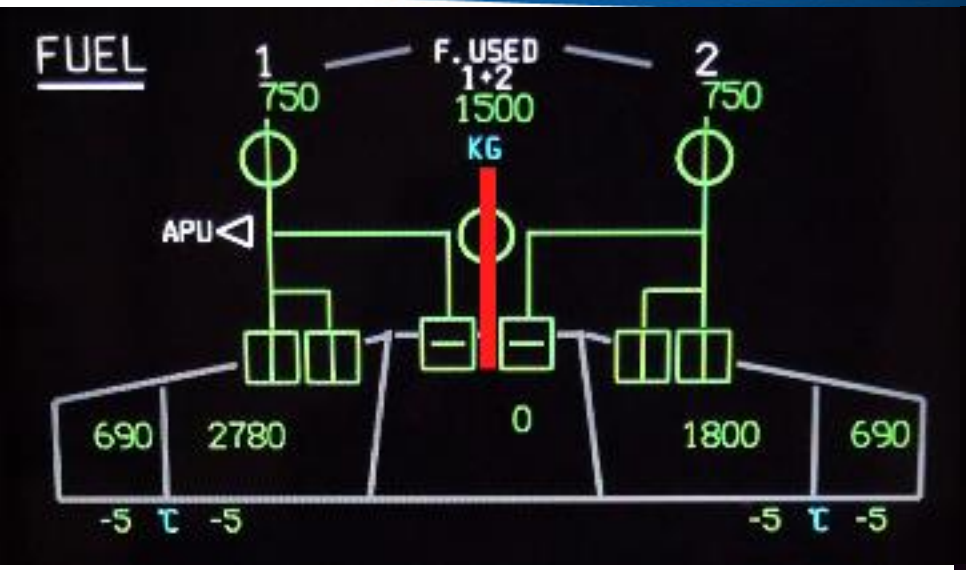


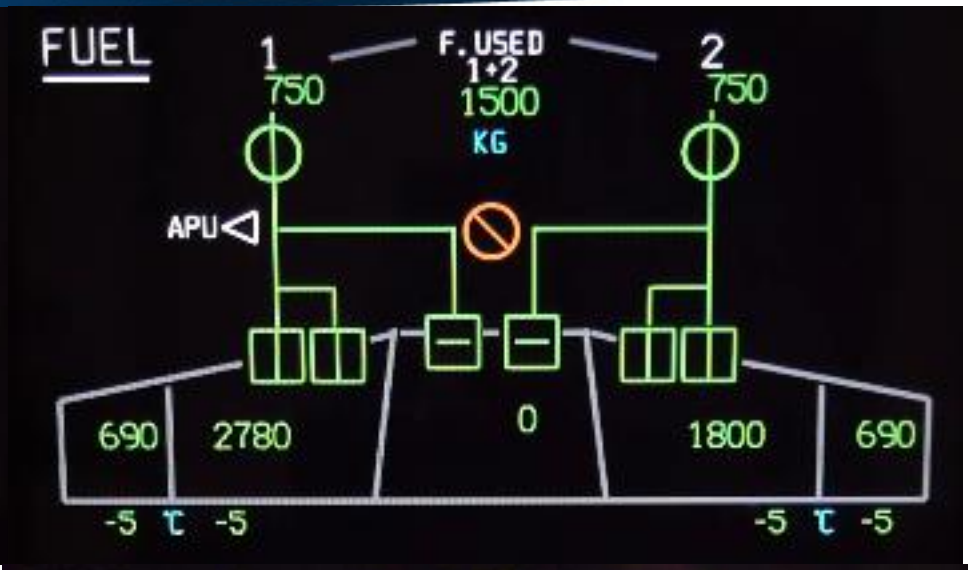




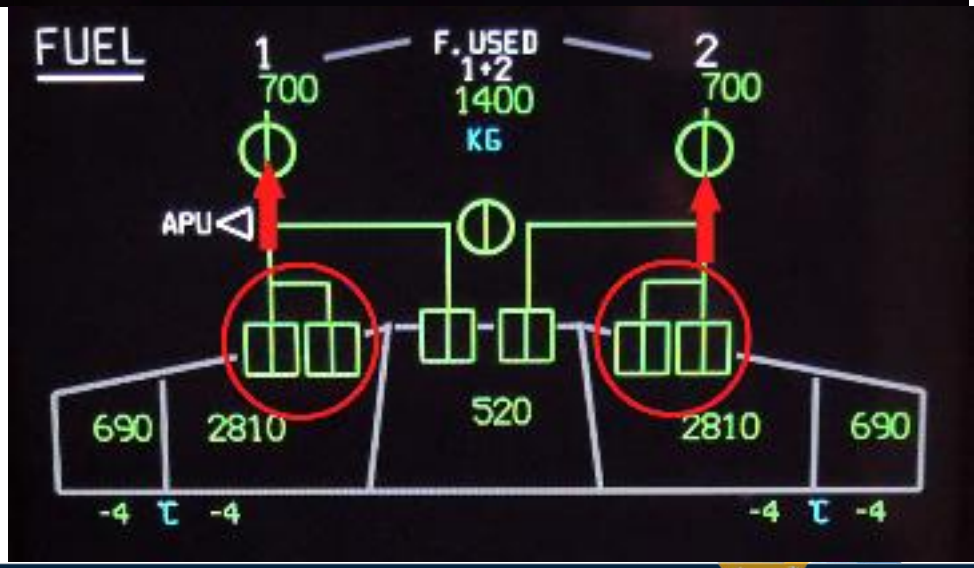


Ecam Fuel Display





- For any abnormality like engine failure, a fuel imbalance could create a further problem.
- Now the cross feed valve comes to play.
- Normally the valve is closed but setting it into open position.
- The fuel then can be transferred from the heavier side to the lighter side using the fuel pump accordingly.
- Suction valves are installed in each wing tank, incase of both fuel pump failure.
- No suction valve in center tank.

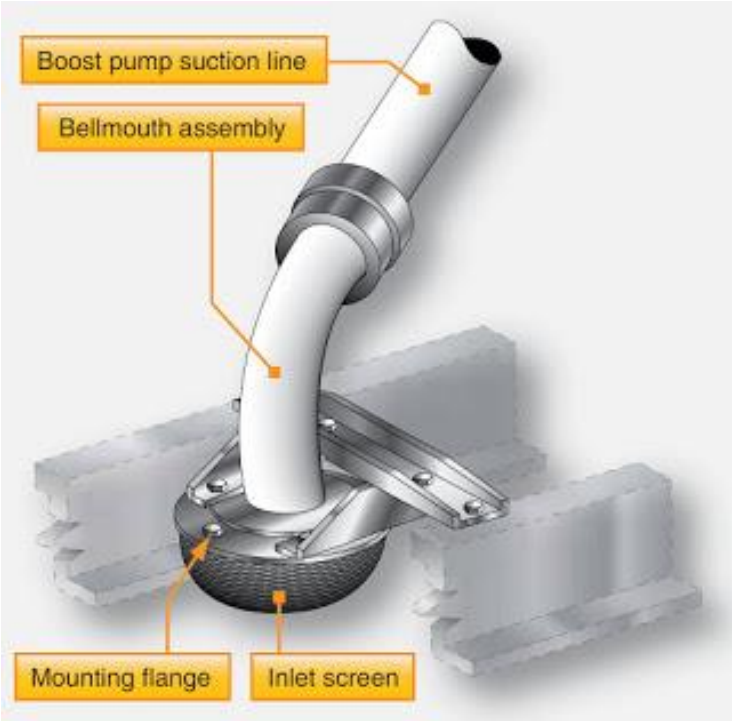


Boost Pumps

- An aircraft fuel boost pump, also known as an auxiliary electric pump.
- It is responsible for delivering fuel to the aircraft engine before the engine starts.
- The aircraft fuel boost pump can also be used to supply fuel to the airplane engine if the engine driven or primary fuel pump fails.

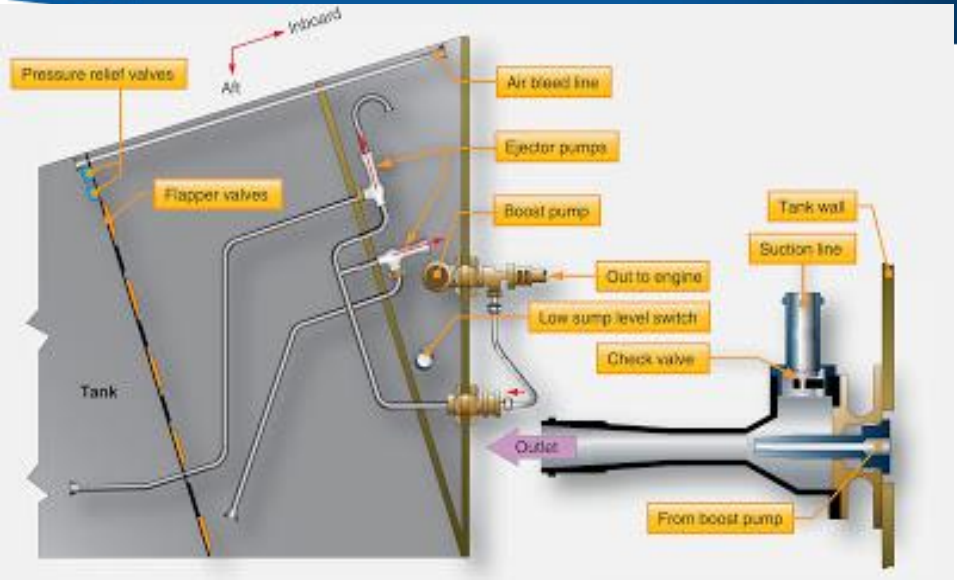
Boost Pumps

- The most common type of auxiliary fuel pump used on aircraft, especially large and high-performance aircraft, is the centrifugal Boost pump.
- It is electric motor driven and most frequently is submerged in the fuel tank or located just outside of the bottom of the tank with the inlet of the pump extending into the tank.
- If the pump is mounted outside the tank, a pump removal valve is typically installed so the pump can be removed without draining the fuel tank.
- The centrifugal boost pump is used to supply the engine-driven fuel pump, back up the engine driven fuel pump, and transfer fuel from tank to tank if the aircraft is so designed.

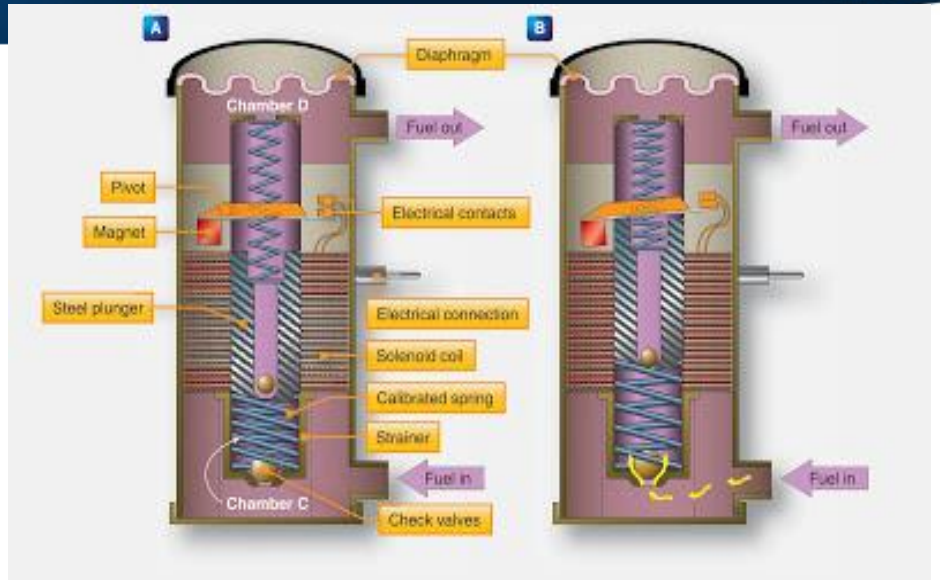


A typical fuel boost pump inlet screen installation for a centrifugal pump mounted outside of the bottom of the tank

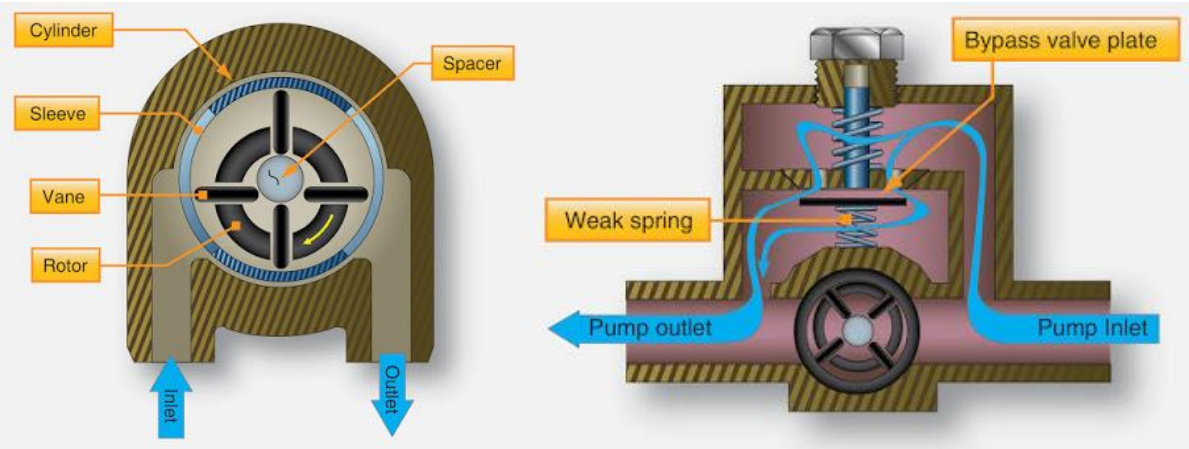
Other Pumps



Ejector Pumps



Pulsating Electric Pumps



Vane-Type Fuel Pumps

Fuel Tank

Fuel Tank Design

- Metal fuel tanks generally are required to withstand an internal test pressure of 3.5 psi without failure or leakage.
- Furthermore, they must withstand without failure any vibration, inertia loads, and fluid and structural loads to which they may be subjected during operation of the aircraft.
- Fuel tanks located within the fuselage of a transport aircraft must be capable of withstanding rupture and retaining the fuel underneath the inertia forces that may be encountered in an emergency landing.
- Rule of Thumb for max. fuel volume: 85% for wing tanks and 92% for fuselage tanks, measured to the external skin surface (exception: bladder tanks, 77% and 83%, respectively)

Fuel Tank

Transport Fuel Tank Design

- The definition of transport wing box is a thicker airfoil with bigger wing planform which the interior can be accessible through access holes for tank sealing and repairing.
- Doublers, or other flat metal strengthening members, are to be so designed that sealing material can be applied where these members intersect or parallel other structure.
- Flange spar caps, ribs and bulkheads, should be kept away from the tank cavity. The tank cavity must be accessible for the replacement of all rivets or other attachments. It should be possible to make any spot repair in the tank within one hour.

Fuel Tank

Transport Fuel Tank Design

- All tank walls should be accessible on both the interior and exterior surfaces so that leakage detection and repair can be readily accomplished.
- Fewer parts mean fewer seams to leak, fewer fasteners penetrating the seal plane, fewer fillets to apply, and less chance of channeling in case of a leak.
- Avoid abrupt section changes and sharp corners in the vicinity of a seal.
- Tank wall intersections of less than 90°increase the difficulty of cleaning, sealing, and repairing seals and therefore decrease the seal plane reliability

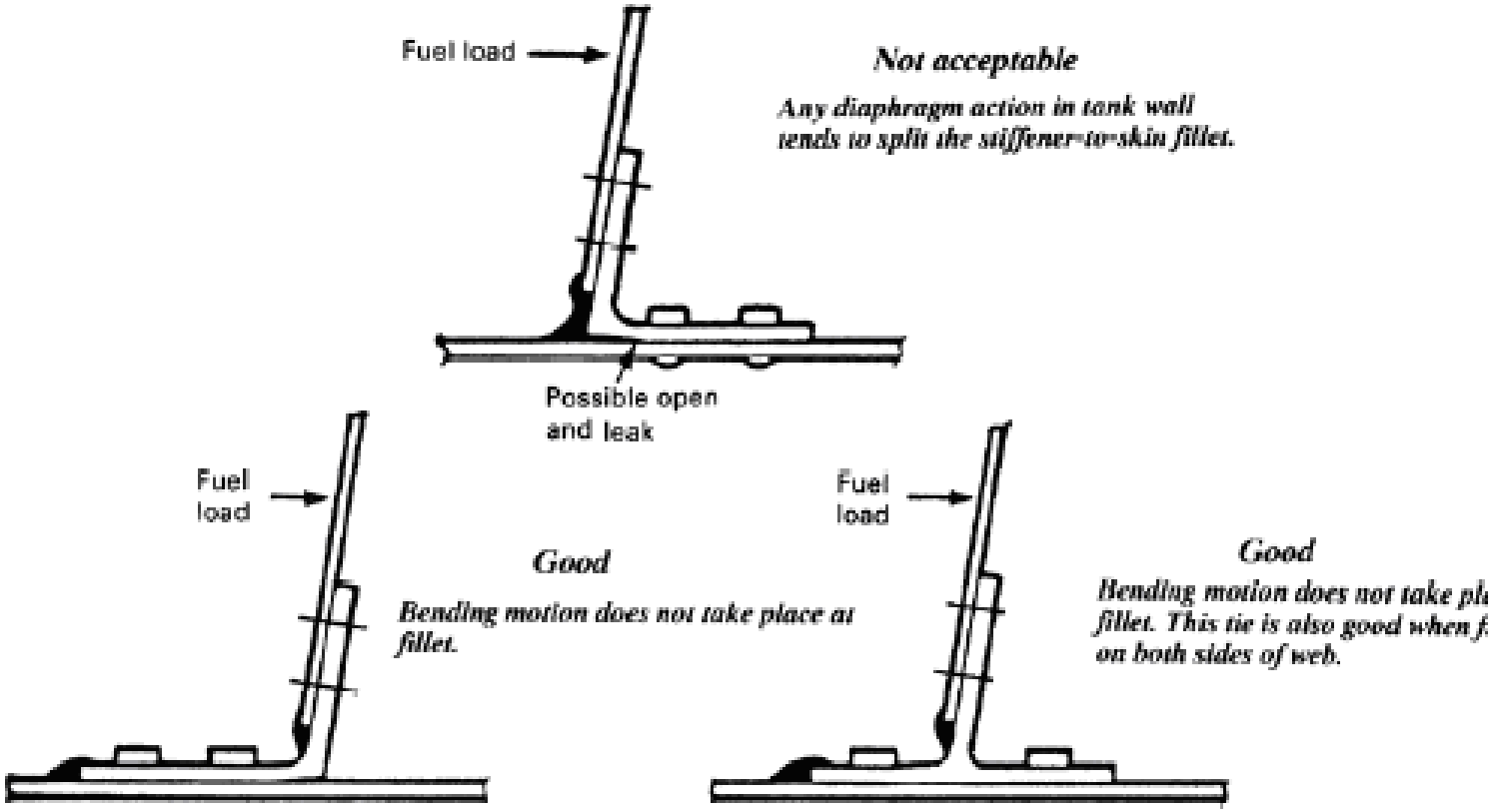
Fuel Tank

Transport Fuel Tank Design

- It is of utmost importance to design integral fuel tank subassemblies (that is , skin panels, spars, tank end ribs) so that they may be as structurally complete on the seal plane as possible prior to major assembly.
- This will generally allow the use of fasteners or bolts to obtain the primary seal gaps, and will greatly facilitate sealing operations.
- All portions of tank should be readily accessible by convenient access doors. Having to crawl through one compartment to reach another may be considered.
- Tubing and equipment should be kept away from tank walls to increase accessibility to scaled walls.

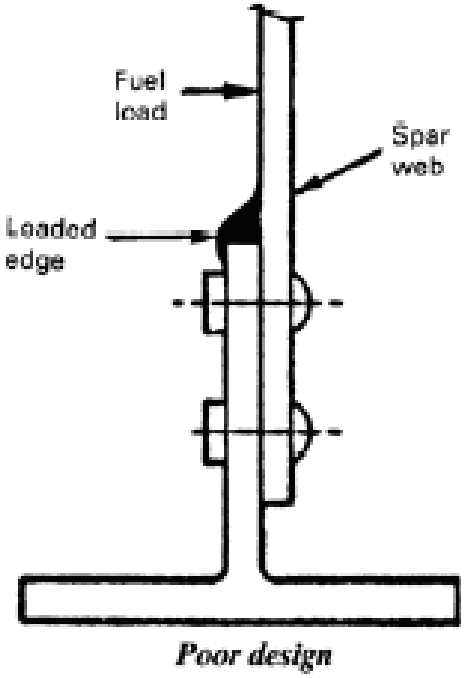
Fuel Tank

Transport Fuel Tank Design

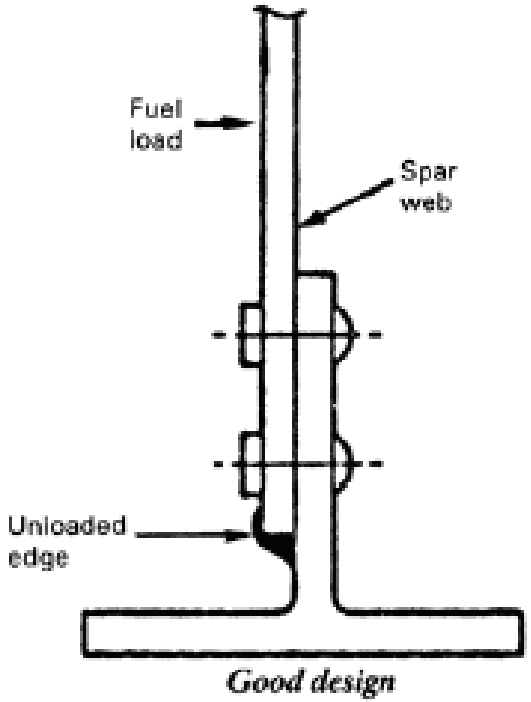


Fuel Tank

Transport Fuel Tank Design



Poor design



Good design

Fuel Tank

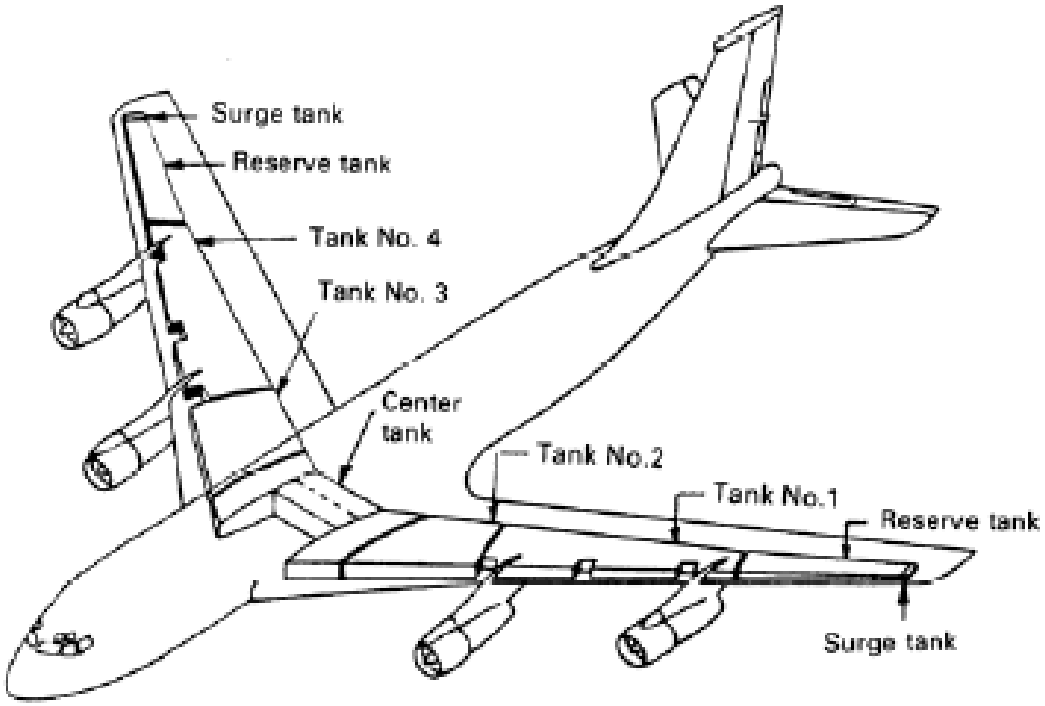
Fuel Management

- Fuel management is an important consideration in the structural design of an aircraft.
- The c.g. fuel management is important with internal fuel tanks.
- The weight of the fuel supply acts down at its c.g. This creates a counterclockwise bending moment at the root. These moments are subtracted to obtain the final root bending moment.

Fuel Tank

Fuel Management

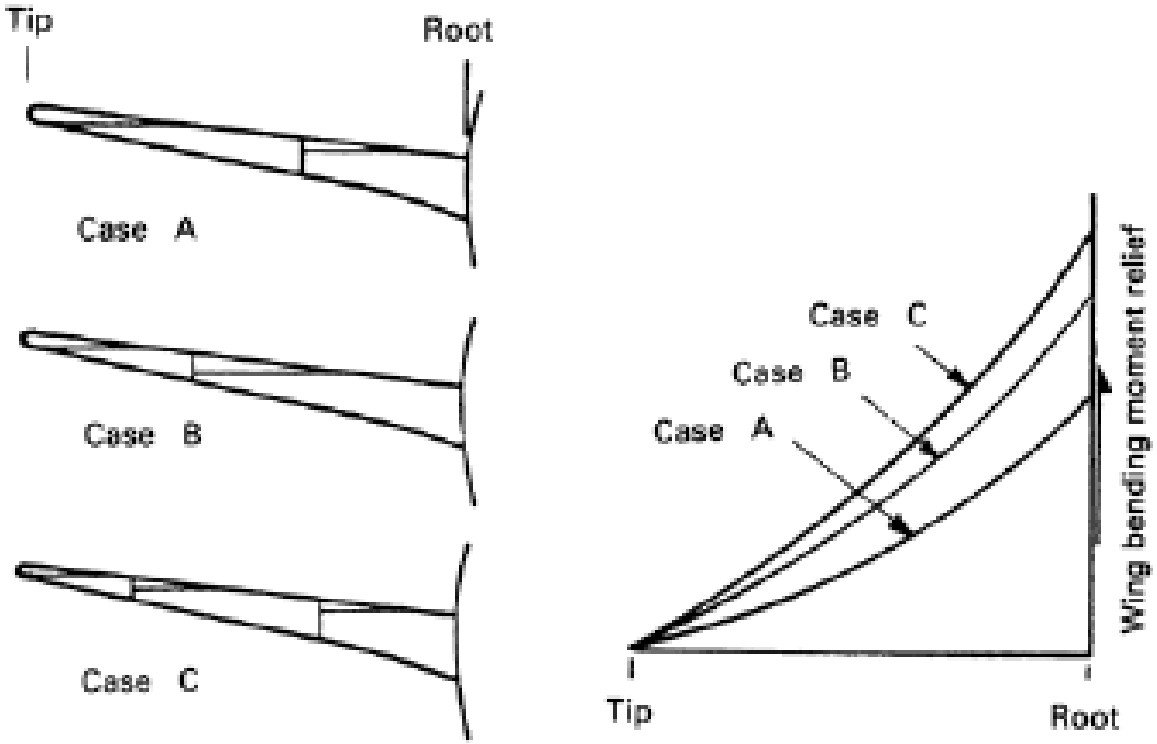
In transport airplanes surge tanks are installed to collect and condense any excess fuel vapor before it exits through the overboard fuel vents.



(a)Fuel tank installation

Fuel Tank

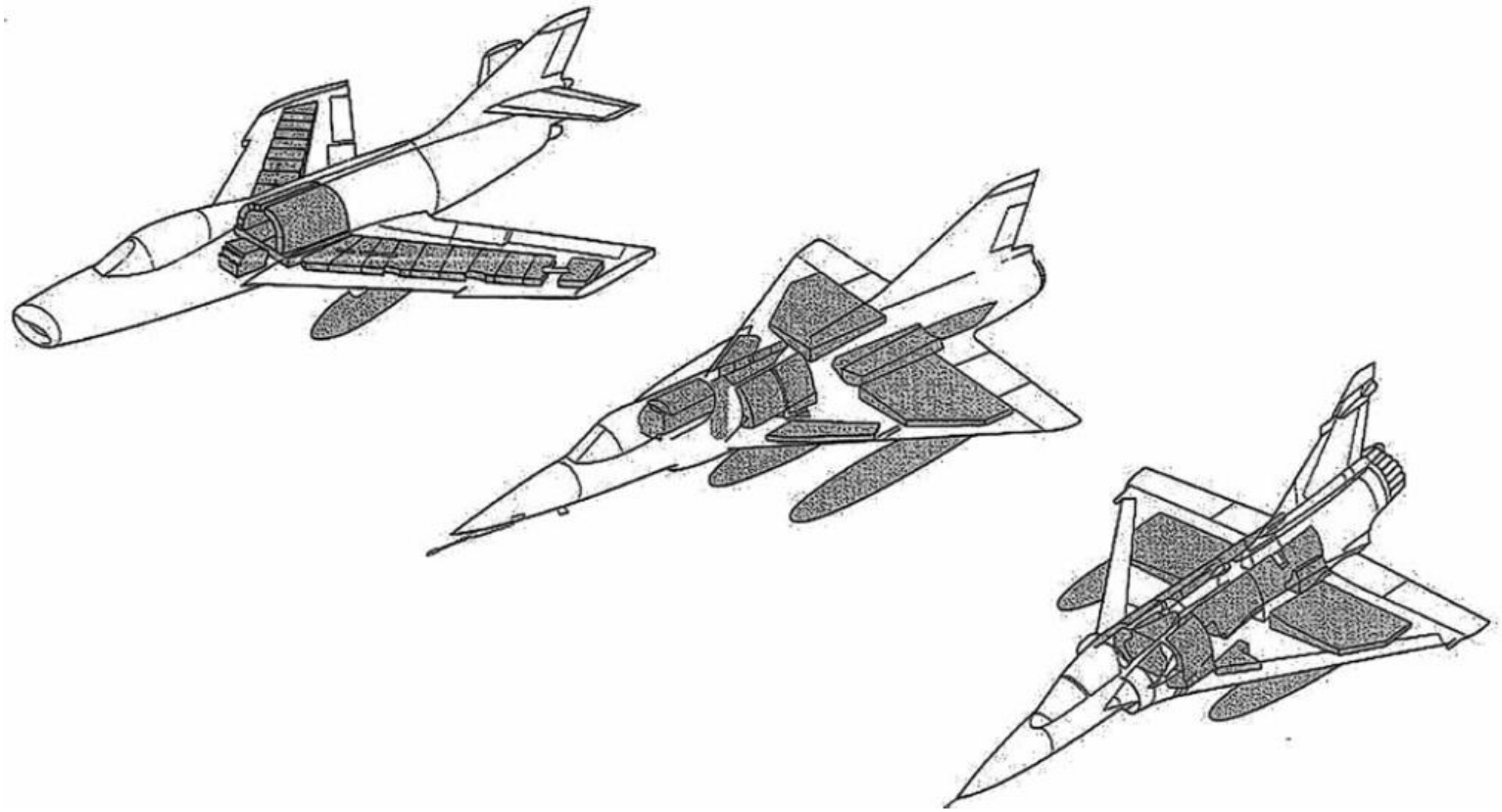
Fuel Management



(b)Fuel tank geometry vs. wing relief

Fig. 8.8.4 Transport fuel tank geometry vs. wing load relief.

Fuel Tanks

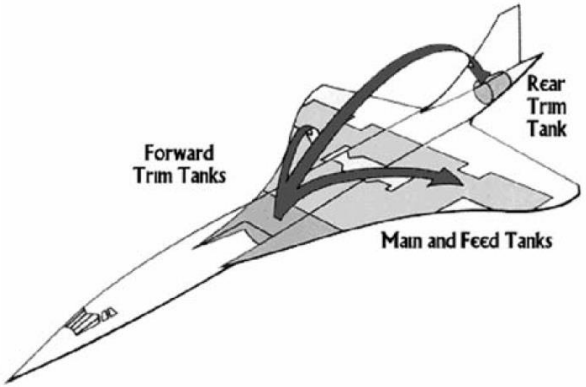


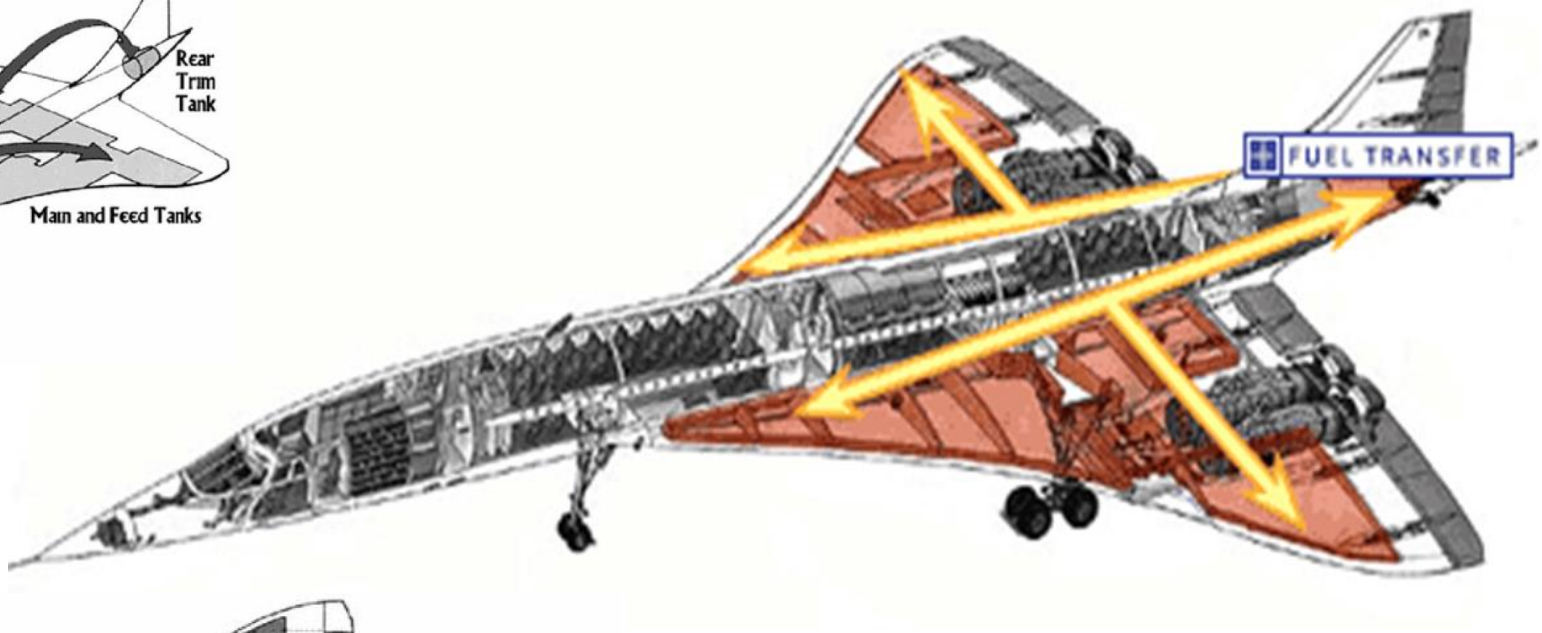
Evolution of typical fuel tank layouts in military aircraft

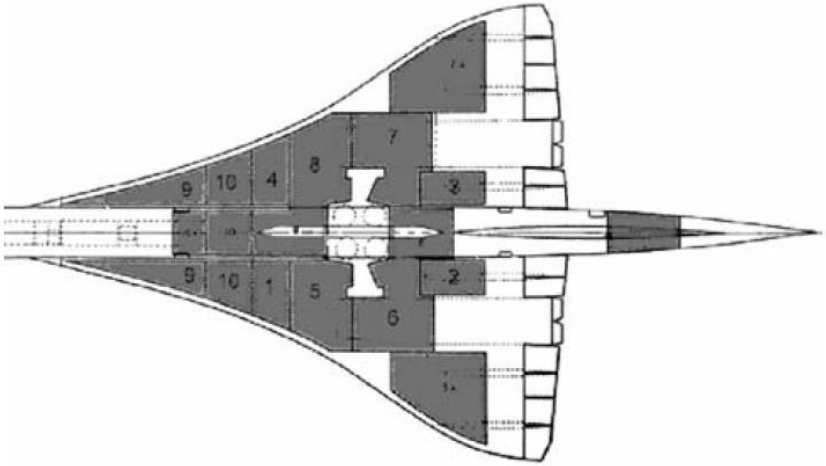
Cross feed & Transfer

Tank-to-tank transfer, especially from one side of an aircraft to another in a single-engine aircraft, is referred to as cross-feed.

Fuel distributed around center of Gravity

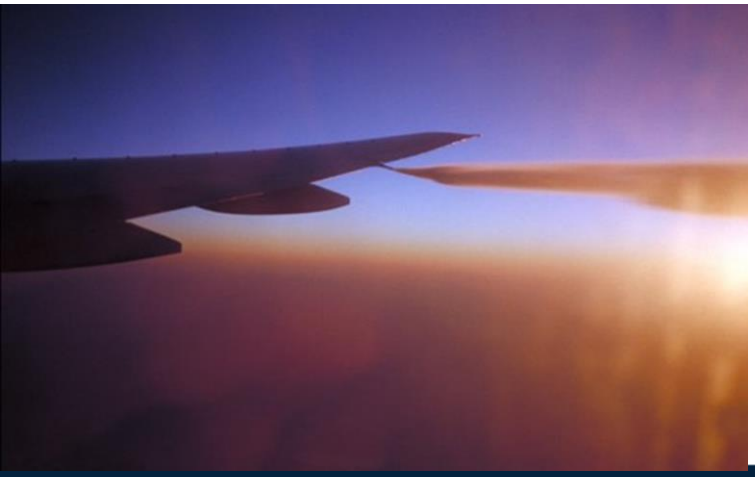






Fuel Dumping Systems

- Needed to meet landing weight limits of landing gear or runway length
- System of fuel pumps and valves
- Usually ejected from wingtips
- Sometimes from aft-most point of fuselage
- Usually designed to allow the plane to go from max take-off weight to max landing weight in 15 minutes or less.



Fuel Dump

In-Flight Refueling

- Original motivation: endurance records
- Currently used only in the military sector
- Two main types:
  - Boom and Receptacle
  - Probe and Drogue