Fuel

Fuel Uses

- **Fuel has several uses on a modern civil airliner:**
  - Power the engines
  - Control of the aircraft centre of gravity and mass distribution
  - Heat sinking for other systems

- The fuel system comprises of tanks, plumbing, pumps and control to facilitate these multiple uses.

What is it?

- Jet fuel is typically kerosene based (e.g. Jet A-1 the world wide standard fuel)

- Jet A-1 has a higher flash point and is less flammable than piston engine fuels *(e.g. AVGAS AViation GASoline)* making it safer to handle.

- Fuel used for international aviation generally attracts no tax *(compare with 175% tax on petrol)*

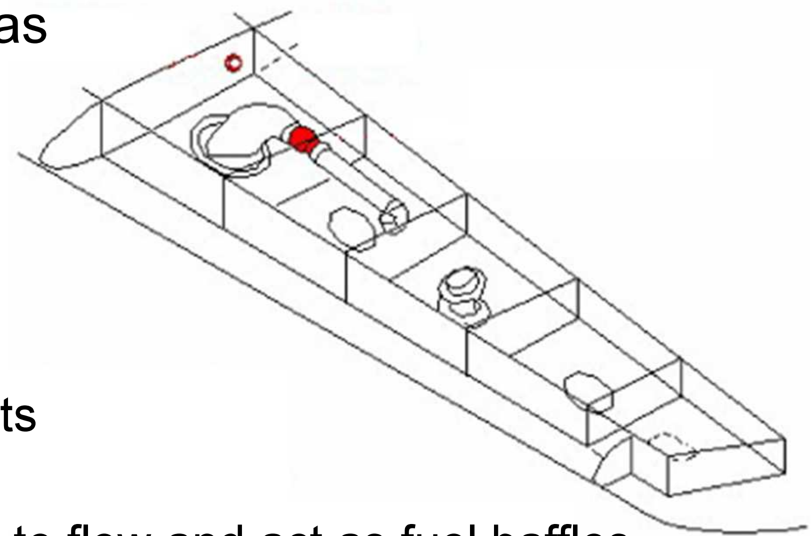
Some numbers

- A380….

MTOW	~ 570 tons
Made up of;	
Plane	~280 tons
Cargo	~ 90 tons
Fuel	~ 200 tons
	(320,000 litres or 70,000 gallons)
	~7m x7m x7m
Maximum range	~ 9,500 miles
Fuel economy	~1/8 mile per gallon.

Fuel storage

- The most efficient location to store the fuel is within the wing box (referred to as the "wet wing")



  - All joint and access panels must be suitably sealed
  - A natural tendency of the fuel to flow towards pumps located at the wing roots is essential.
  - Intermediate ribs have to allow the fuel to flow and act as fuel baffles (to prevent sloshing during manoeuvring).
  - The wet wings may extend to the fuselage centre line or end at the root ribs.
  - Provisions for protection of the tank in the case of belly landing (skid) must be made.

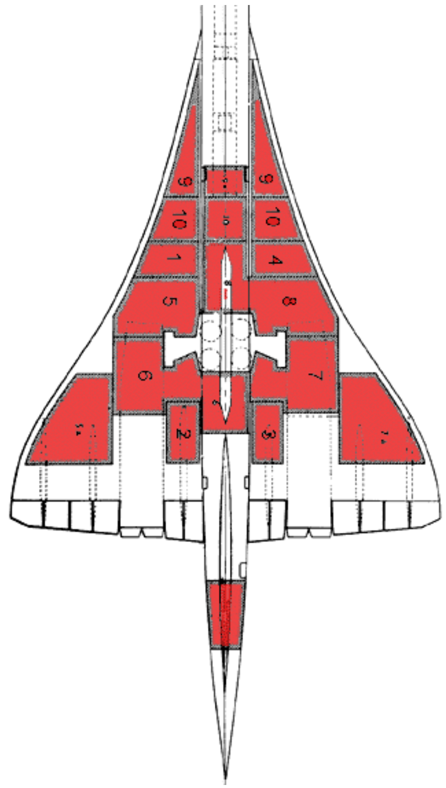
Fuel storage

- Generally 90% of wing volume between spars and skin outer surface is usable; although this may vary from only 75% near the tip to 95% near the root.
  - Loss is made up of
    - Structure displacement : 5%
    - Expansion space (mandatory) : 2%
    - Trapped air : 1%
    - Unusable fuel : 0.5%
    - Equipment displacement : 1%
    - Sealant : 0.5%

- In the case where the fuel volume in the wing is not sufficient, fuel may be stored elsewhere
  - Cabin under floor
  - Aft fuselage or tail cone
  - Cabin tanks ahead of the fuselage pressure bulkhead
  - Wet empennage (trim tanks)

Fuel tanks

Generic civil airliner

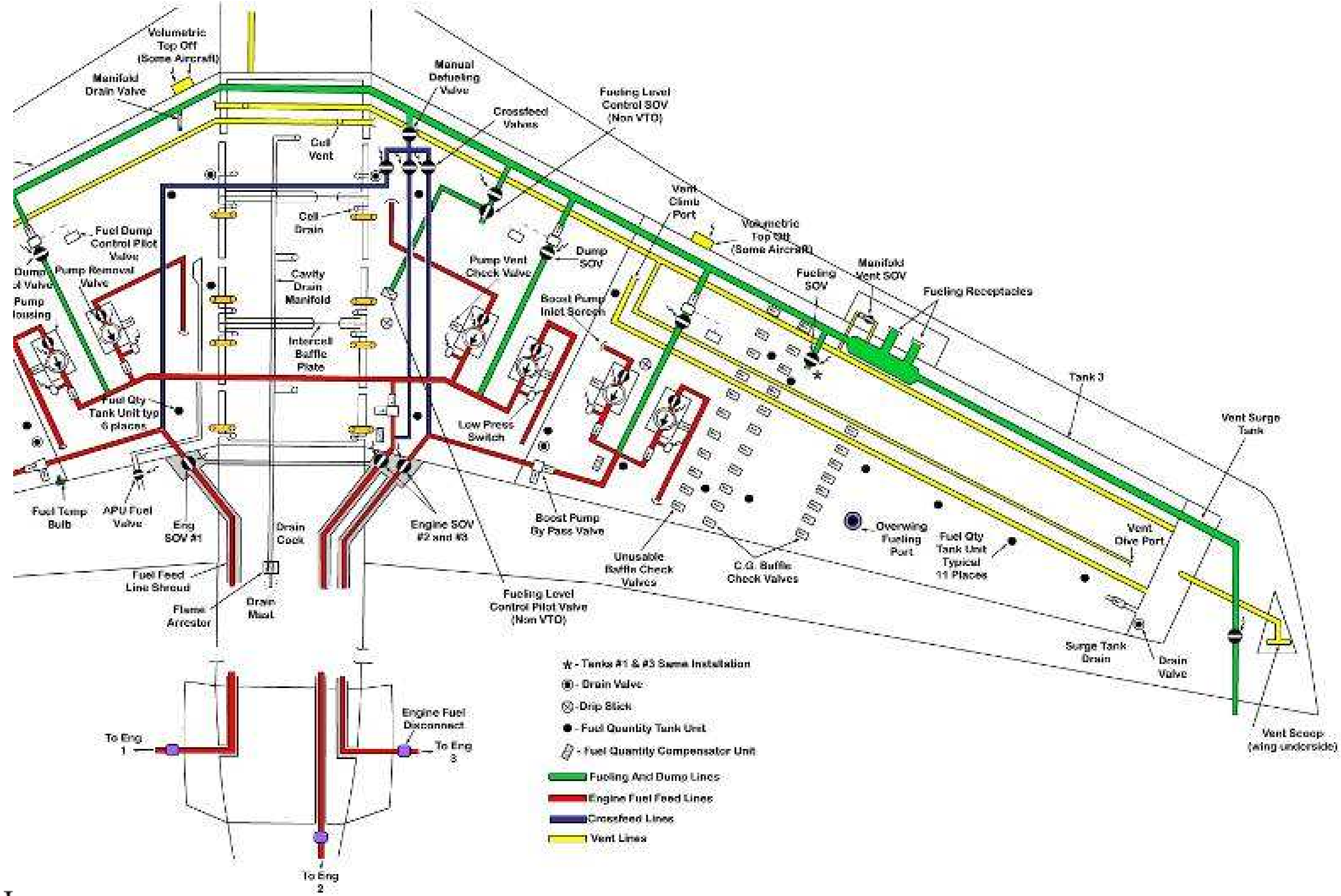


Concorde

Fuel gauging

- Since running out of fuel has dire consequences it is important to put enough in and know how much is used.
- Capacitance systems - Measure the variation of capacitance between the two concentric tubes immersed in the fuel.
- Ultra sonic systems - Measure the time of an echo from the fuel surface.
- Fuel measuring systems are referred to by their precision;
  - Class I approx. 5% accurate in-flight
  - Class II approx. 2% accurate in-flight (business and regional aircraft)
  - Class III approx. 1% accurate in-flight (long-range business and commercial aircraft); best precision today is no better than 0.5% accurate

727 fuel system



Fuel delivery

- The ideal primary delivery system is by gravity; It is simple, lightweight, cost effective and very reliable.
  - Not utilised as a primary delivery system for almost all modern transport aircraft.

- Most aircraft use powered systems;
  - Motive flow
    - It uses a small quantity of high pressure fuel provided by a mechanical pump at the engine to power a jet (ejector) pump at the wing tank.
    - Apart from the HMU at the engine, this system uses no mechanical moving parts, making it simple, low cost, and extremely reliable
  - Hydraulic/electric pumps

Fuel Issues

- Fuel freezing
  - Water in fuel may freeze out and cause a blockage.
  - Fuel is monitored for water content and can be heated.
- Venting/inerting of the fuel tanks
  - Tanks must be vented to allow air in and out during use and re-fuelling
  - This creates ‘ullage’ - space above the liquid fuel filled with air and fuel vapour. At certain ratios the mixture of fuel-to-air is explosive.
  - Inerting involves using a gas, e.g. nitrogen to fill the void rather than air. Other systems use a bladder to contain the fuel.
  - The technology is costly and the general approach has been to limit ignition sources through regulation.

Fuel Issues

- A380….

MTOW	~ 570 tons
Made up of;	
Plane	~ 280 tons
Cargo	~ 90 tons
Fuel	~ 200 tons
– Max landing weight	~390 tons

On larger aircraft it is necessary to be significantly lighter to land than to take-off. Normally fuel burn in flight takes care of this but if an emergency landing is required it may be necessary to jettison fuel.

Re-fuelling

- Gravity fuelling is done by pouring fuel through an opening on top of the wing at around 75% wing tank span
  - This location is chosen such that it is impossible to over-fuel the aircraft.
  - Fuel brought to this level should leave a large enough “air bubble” for the proper functioning of the fuel system

- Modern aircraft also have pressurized refuelling capability
  - A panel typically at a wing root or under a wing allows a connection to a standard fuel nozzle from a fuelling truck – an aircraft may have multiple nozzles
  - Pressure of 40 to 50 psi for fuelling and -8 to -3 psi for de-fuelling
  - Typical fuelling rates are 100’s Gallons per minute per nozzle – a large aircraft can take some time to refuel.

Energy in refuelling

- We normally think of the power during flight as limiting the possibility of battery powered aircraft, but what about recharging batteries?
  - An A380 flies for ~17 hours on a full tank of fuel
  - It can be refuelled in less then an hour……
  - If we have 4 nozzles each feeding 32 l/sec and A1 jet fuel has an energy density of 53 MJ/l, the ‘power’ is:
  - 4 x 32 x 53 = 6784 MW!!!
  - For reference Hinkley ‘c’ will be 3200MW……….