Fuels 201

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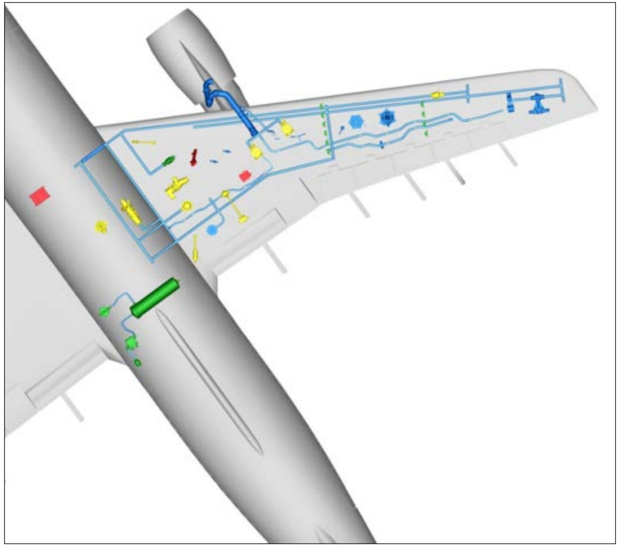
Agenda

Presentation of major fuel system elements

- Fuel distribution system
- Fuel measurement (Gauging)
- Fuel tank inerting / flammability reduction

Q & A Session



- Fuel distribution and vent systems
- Inerting system
- Fuel quantity indicating system
- Conveyance

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Fuel distribution system

- Refuel / defuel
- Engine feed
- APU feed
- Fuel transfer
- Vent system
- Water management & tank draining

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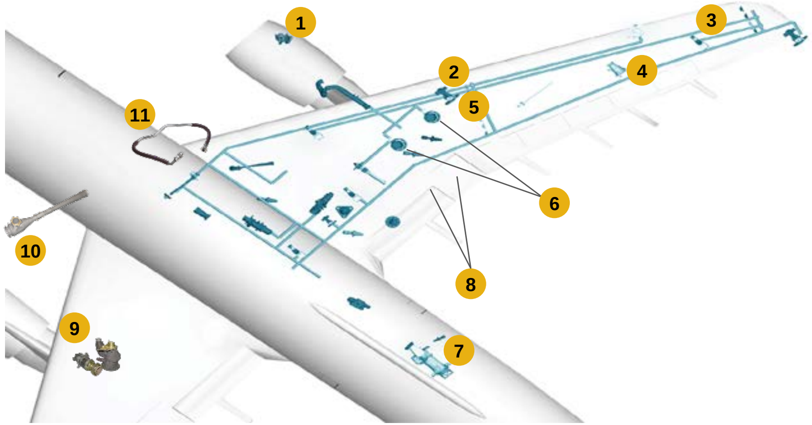
Airframe fuel distribution systems



5  Twin motor actuator

6  Engine feed pumps

7  Trim transfer pump

8  Pressure transducer

9  Override jettison pump

10  Jet pump

11  Engine feed tube

1  Technologically advanced thermally efficient fuel pump

3  Check valve

2  Pedestal mounted ball valve

4  Refuel valve

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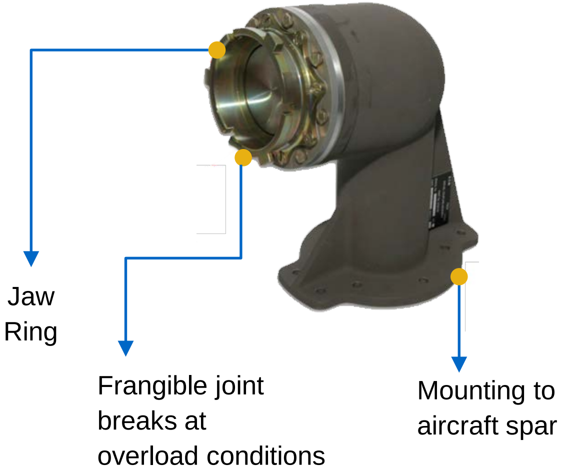
On-aircraft refueling

Aircraft pressure refueling coupling



- Frangible Jaw Ring
  - Excessive side loading can result in breakage

Note: As a safety feature the frangible jaw ring is designed to shear when excessive force is applied

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Refueling cover

Overwing fueling adaptor

Used in the rare event that the fuel pressure refueling system is inoperative or malfunctioning

Wing tanks can be refuelled individually with handheld trigger nozzle

Refueling times are extended but allow the aircraft to be refueled manually

Overwing adaptor

Overwing refueling cap

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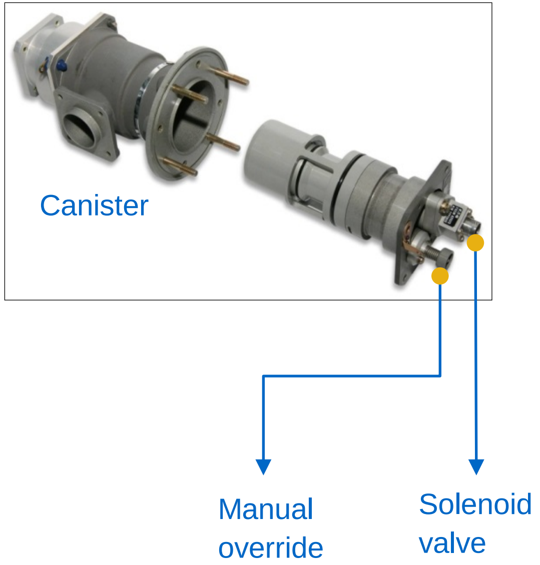
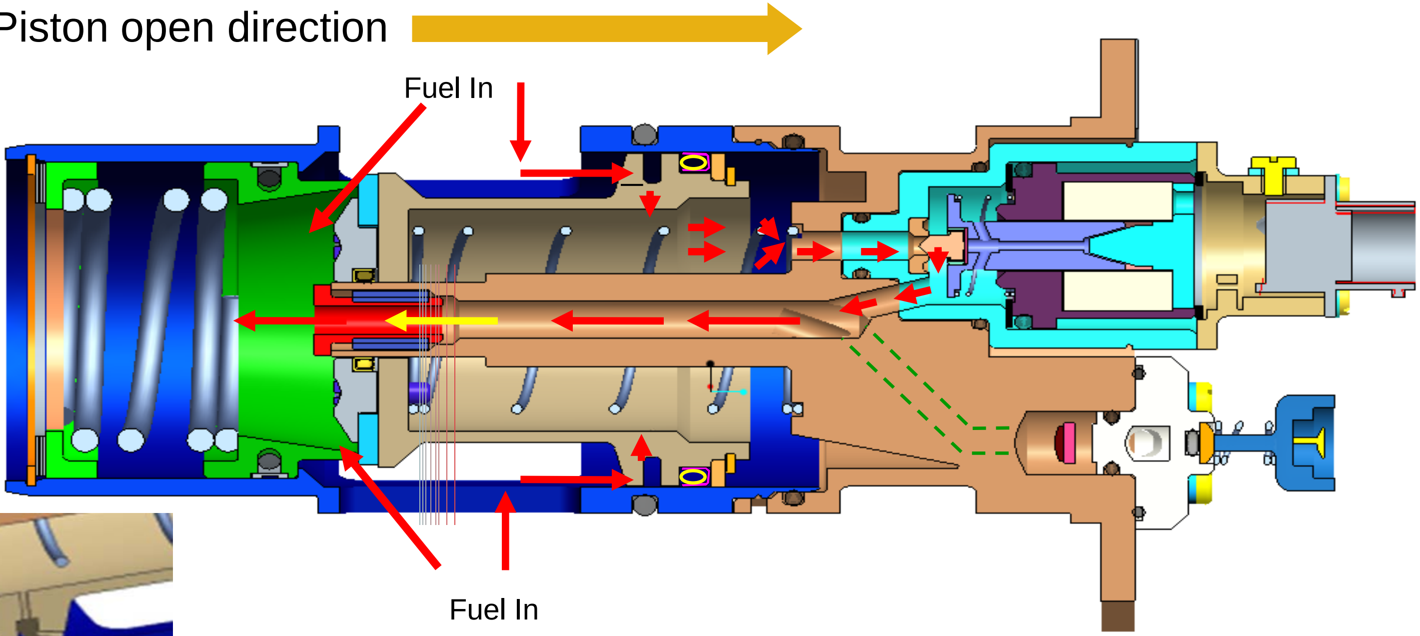
Refuel control panel

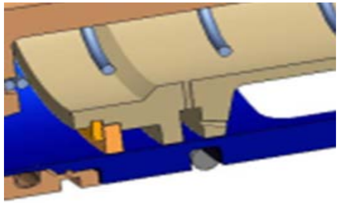
Pressure refuelling valves and canisters

- The refueling valve (rated at 120 PSI and 110 IPGM) is operated by a solenoid which is linked to pressure switches in the tanks which sense that the pressure is building up as the fuel levels rise
- In the unlikely event of a solenoid failure, there is a manual override facility which the refueling operator can use to manually refuel the Aircraft
- Canisters are fitted to the aircraft spar and allow the pressure refueling valve to be removed from the canister without spillage of fuel as a non-return valve automatically closes as the refueling valve is removed



Fuel flow path





Engine feed system

Fuel boost pumps and canisters

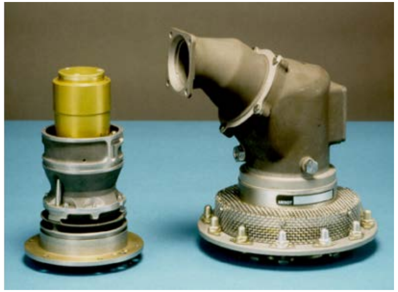
Two general configurations for most medium – large commercial aircraft:

- Base-mounted through the lower surface of the wing
- Rear spar-mounted

Pros and cons of each design, including:

- Base-mounted
  - Pump inlet low in tank and improves pump-down
  - May be concerns over pump location and stress raisers
  - Routing of power supply leads and protection of connectors
- Spar-mounted
  - Pump above base of tank so reprime stage required, increasing power level

Base-mounted pump and canister



Spar-mounted Pump and canister

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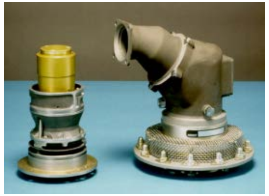
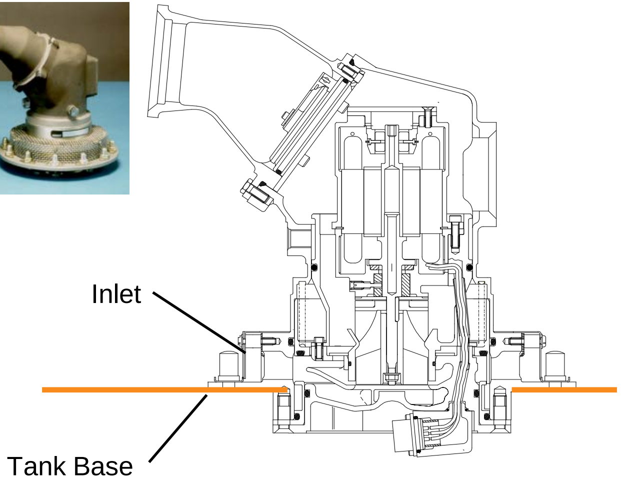
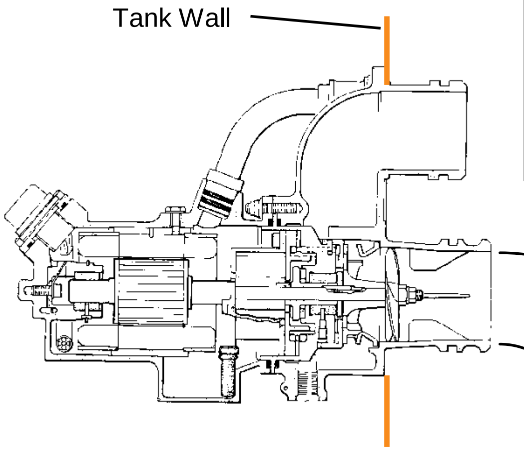
Fuel pump location options

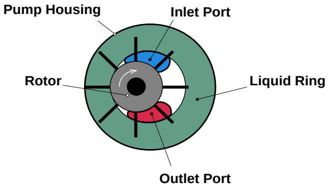
Base mounted





Spar mounted

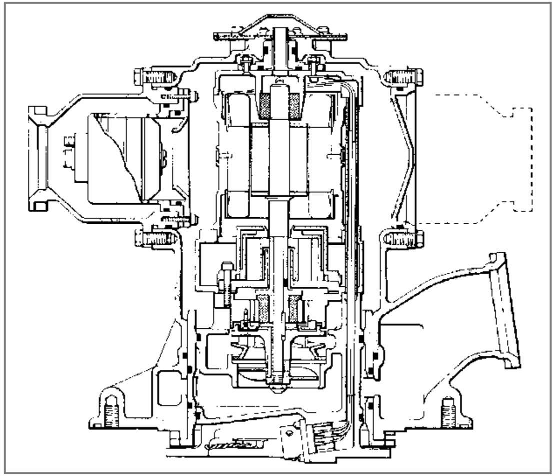




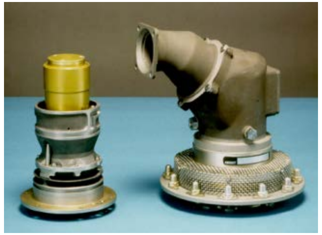
Pump – Base-mounted with remote inlet

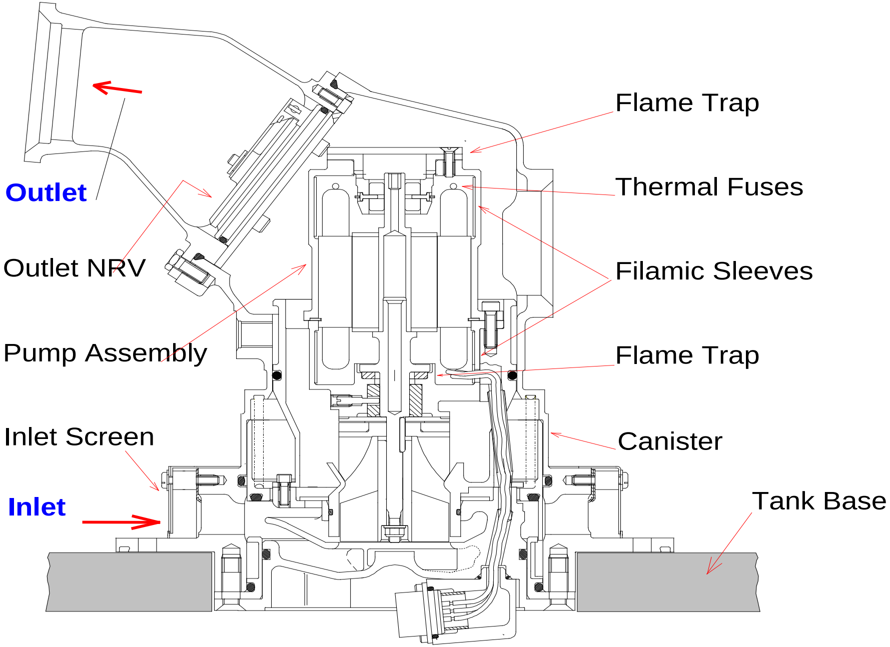
Occasionally it is necessary to incorporate a remote inlet with a base-mounted pump

- Unable to position pump at the lowest point of the tank for accessibility or stress concerns
- Results in use of reprime stage within the pump



Typical fuel pump features





- 3 phase AC Induction motor
- Motor - cooled by fuel
- Carbon bearings - lubricated by fuel
- Motor windings protected by thermal fuses
- Pump self priming – either directly or through use of a reprime stage

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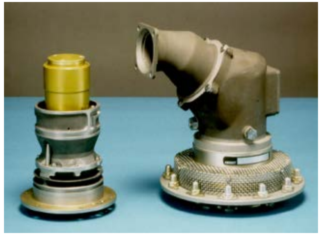
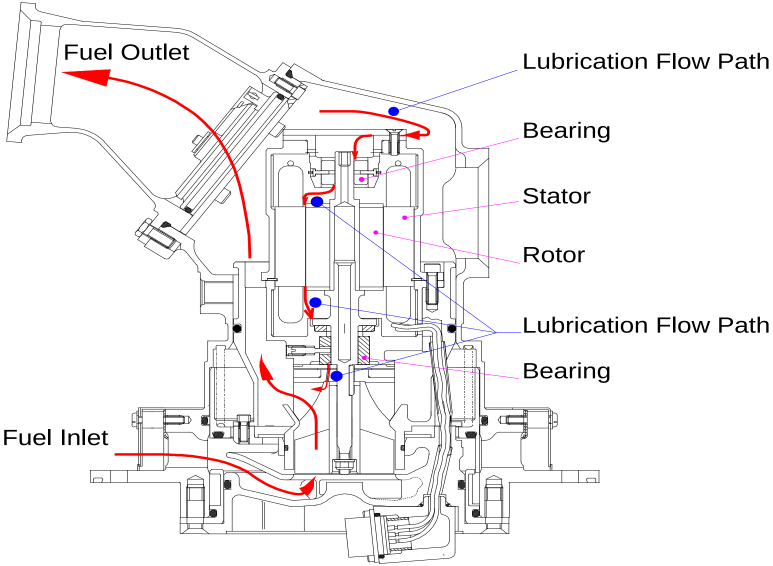
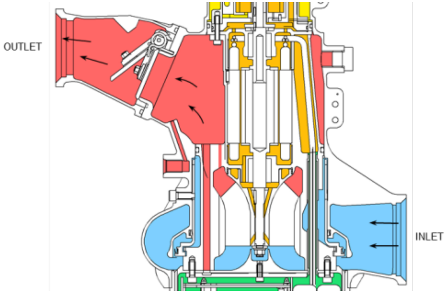
Pump operation







- Fuel enters the pump through a coarse strainer – sized to meet blockage & icing requirements
- Pumped through inducer & impeller combination or mixed flow impeller
- Passes around outside of motor, through an outlet NRV
- HP fuel passes through the motor, via flame traps, to provide internal cooling and lubrication

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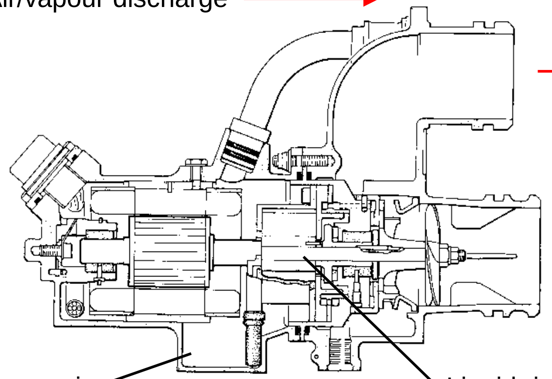
Typical horizontally-mounted pump



- Design generally similar to that of vertically-mounted pump
- Liquid ring stage added
  - Remains flooded at all times and extracts air, vapour or fuel from the pump inlet line continuously – ensuring impeller sees fuel

Variable frequency power use

Historically, large commercial transport aircraft have used pumps powered from a 400Hz 3-phase power supply and employing a simple, reliable 3-phase induction motor

- With the introduction of variable frequency power systems induction motors are not always suitable over the frequency/operating range

It may be possible to use modified induction motor designs for some applications. However, for other applications it may be necessary to incorporate electronic power conversion:

- Variable frequency – constant frequency
- Variable frequency – DC

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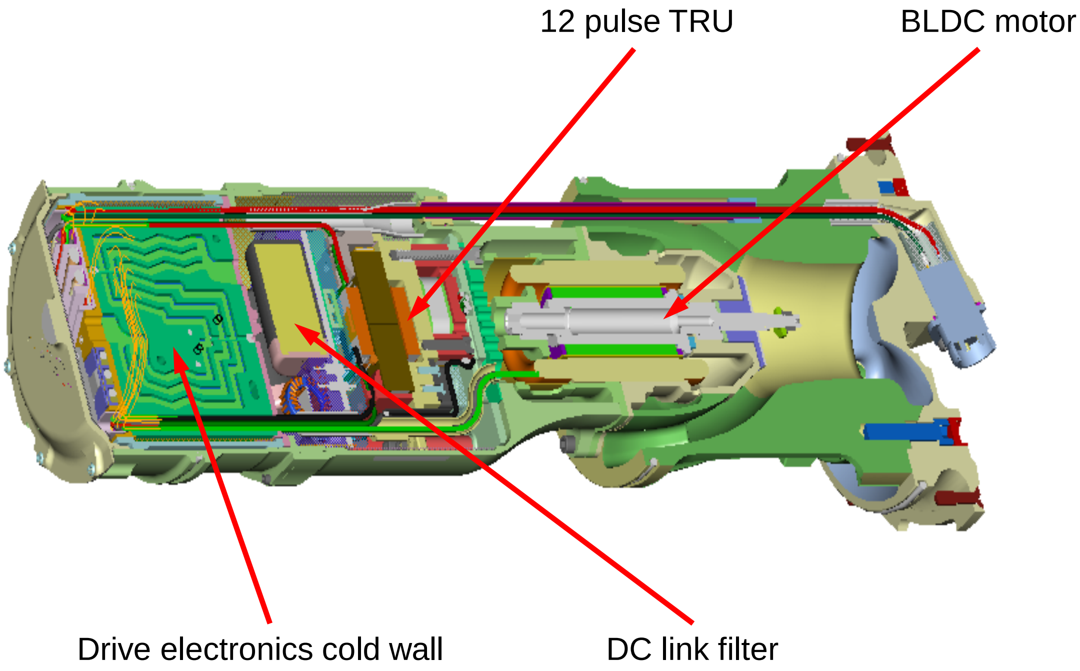
Feed pump with integral power conversion

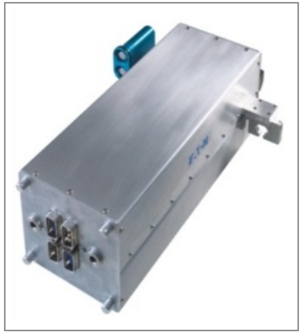


Fuel pump with remote power conversion

- Conventional 3-phase ac-powered pump & housing with remote electrical power conversion (inverter)
- Could be Brushless DC with remote electronics, dependent on operational requirements

Pump and housing

Remote inverter



FAR 25.981 implications for fuel pumps

- Impacts design of pumps to ensure protection against electrical failure, lightning strike, etc.
  - Bonding & earthing of components to structure
  - Isolation of electrical power source from internal fuel system
  - Improved protection of electrically-driven fuel pumps
    - Insulation and isolation
    - Flame trap design and location
    - Material selection

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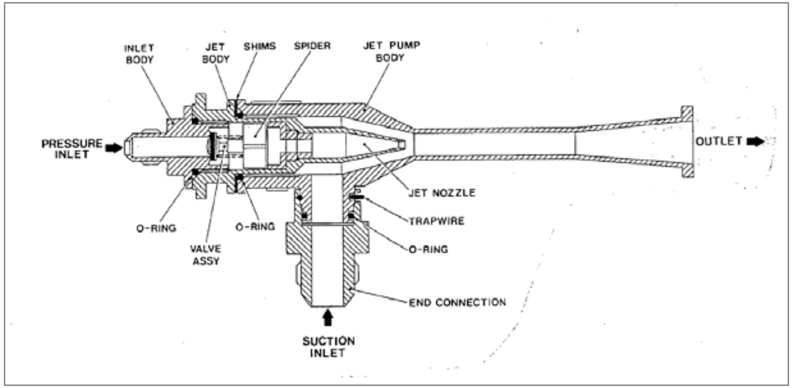
Jet pumps

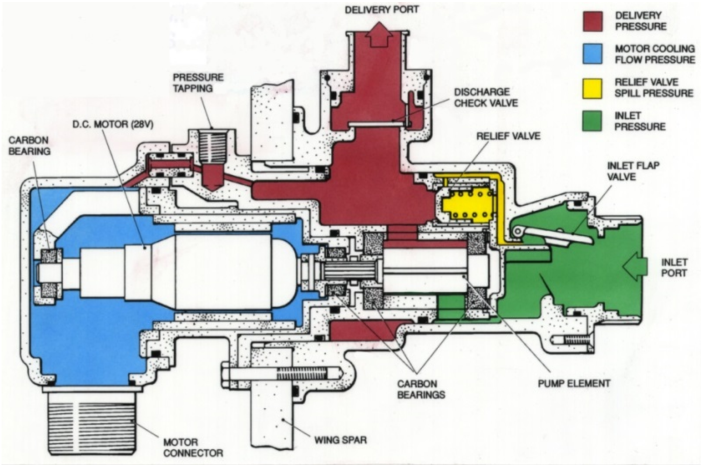
- May be used for various applications within the fuel system, including:
  - Main engine feed (typically small & mid-size a/c)
  - Tank – tank fuel transfer
  - Keep collector cell/feed tank full
  - Fuel & water scavenge
- High pressure fuel flow to the nozzle (from fuel boost pump or engine return)
- Secondary (induced) flow – usually from fuel tank
  - For engine feed, fuel transfer or water scavenge
- Pump optimised to provide sufficient outlet pressure for engine feed or transfer
- No moving parts – high reliability but low efficiency



APU feed system

APU Pump and housing

- Dual purpose
  - APU supply & emergency engine relight
- Canister mounted on rear spar
- Dry running capability
- Fuel flooded brushed DC motor with RFI suppression
- Reliable, maintenance-free operation
- Explosion-proof and thermally protected motor
- Demonstrated tolerance to contaminated fuel



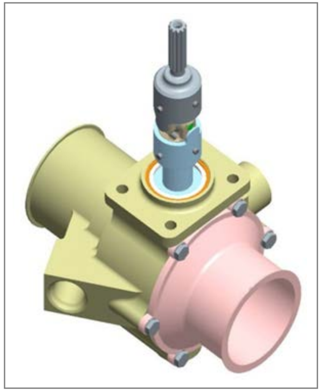
Fuel valves

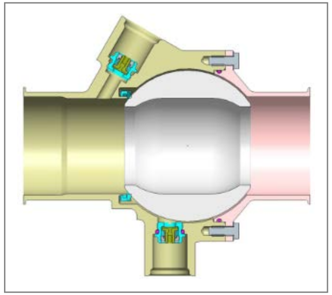
Flow control valves

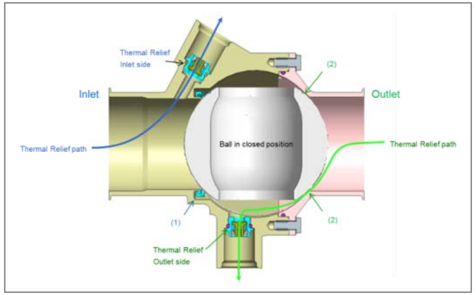
- May be used for a variety of purposes, including: engine shut-off, transfer control, refuel control, jettison
- Typically electrically-actuated ball valves for commercial aircraft, although can be other designs, including: butterfly & gate valves
- May be line-mounted or bulkhead-mounted (e.g. pedestal, remote shaft-driven)
- May require thermal relief to prevent over-pressurization of fuel lines

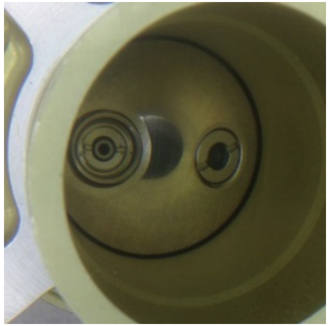
Thermal relief valve operation

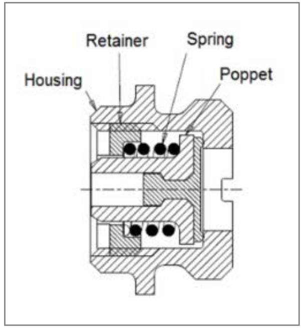
- One or more thermal relief valves may be fitted to the valve
- Either on the valve ball or in the body
- Allow pressure relief of sealed areas in pipework due to thermal expansion of the fuel











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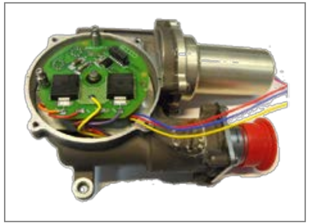
FAR 25.981 & composite wing impacts

- Valve and actuators designs need to ensure protection against electrical failure, lightning strike and galvanic corrosion
  - Bonding & earthing of components to structure
  - Isolation of electrical power source from internal fuel system
  - Selection of materials and corrosion protection

Actuator developments

- Further development of fault isolation and prevention
- Actuator reliability improvement
  - Elimination of mechanical / electromechanical position sensors and replacement with alternative devices
  - Revised gearbox design



Vent system

Tank fuel vent valves

- As the fuel enters the tanks it is essential that the air in the tanks which is displaced by the fuel is vented overboard, this is achieved by Air No Fuel or Vent valves fitted in the top of the Aircraft tanks
- As the tanks fill up the air is vented through the vent valves and is discharged overboard
- The valve has a float assembly linked to a valve seat which floats on the fuel. When the fuel level reaches the prescribed level in the top of the tank the valve seat closes, thus preventing overboard fuel leakage
- The valve also allows air to enter the airspace above the fuel to prevent vacuum in the tank
- Product range includes valves with pressure relief to prevent over-pressurization of the fuel tanks

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Water scavenge and drain

Water scavenge systems

Jet pumps

- Fitted in the bottom of the fuel tank
- With a motive flow it uses the Venturi effect to draw water and fuel from the bottom of the fuel tank, emulsifying this mixture with the primary flow before entry into the system

Water drain valves

- Water drain valves are fitted in the bottom of fuel tanks
- A non return valve within the unit is operated externally and excess water is collected from the wing by use of an adaptor and collector bottle

Moves to a more comprehensive active water management system

Jet pump

Water drain valve and adaptor

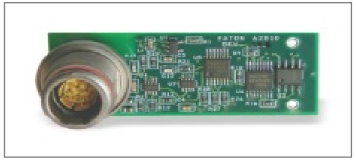
Fuel measurement

Eaton digital gauging system

- Eaton's digital fuel gauging system provides a cost-effective solution to replace analogue devices
- The technology resolves many problems and deficiencies found in older technologies, with the following benefits
  - Lightweight, Rigid probes & low mass harness
  - Improved Self-Healing – detection of water
  - High reliability and low life cycle cost

Probe with compensator

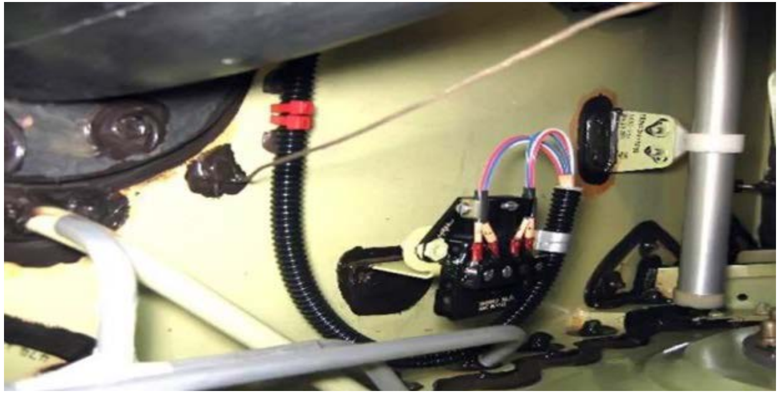
Capacitance – digital circuit

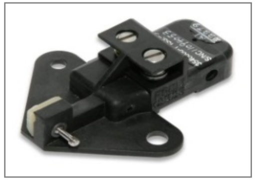


Remote data concentrator

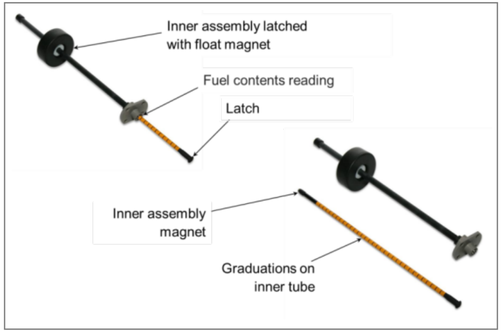
Fuel monitoring

Typical component location



Level sensor	Temperature sensor	Pressure switch
		

- MFLIs used as a secondary back up system if the aircraft FCMC is inoperative
- Manual readings are taken from the MFLIs in each tank on the aircraft
- The pilot can allow the aircraft to depart with these manual readings with the complete assurance that the aircraft has enough fuel to complete the flight plus an acceptable safety margin



Fuel tank inerting

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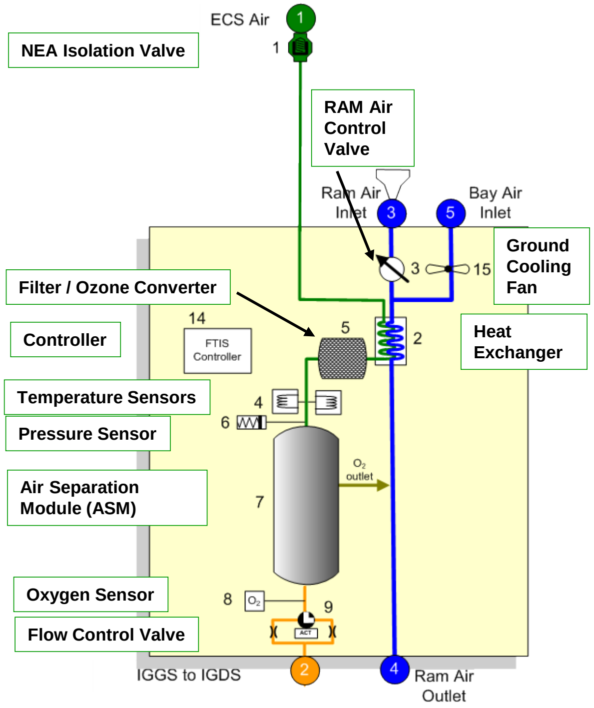
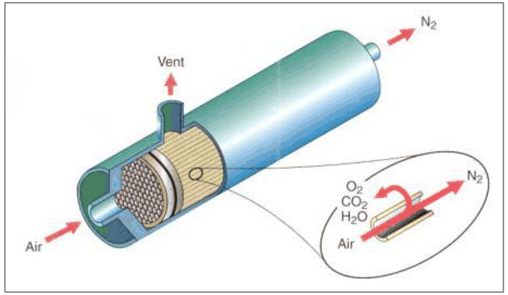
Fuel tank inerting system architecture



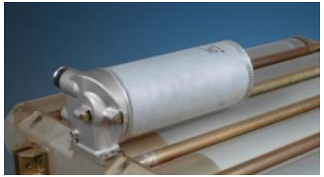
- Isolation Valves shut off NEA flow to fuel tank when required based on temperature Sensor signals
- RAM Air Control Valve and Heat Exchanger control temperature at ASM inlet
- Filter and Ozone Converter remove contaminants
- ASM reduces oxygen level, discharges oxygen overboard
- Flow control valve sets flow rate for climb, cruise or descent
- Temperature, Pressure and Oxygen sensors provide signals to IEMS for health / status monitoring
- OEA and Heat Exchanger Outlet combined in ram outlet duct



Inerting components

- Air separation modules
- Ozone converter/particulate filter
- Flow sensor
- Oxygen sensor
- Pressure regulation valves
- High temperature air valves
- Flow control valves
- Inerting controller
- Electric motor driven compressor (option)

Integrated ozone converter and particulate filter



Bleed pressure regulator

Inerting controller

Ram air flow control valve

Electric motor driven compressor

HFM separator

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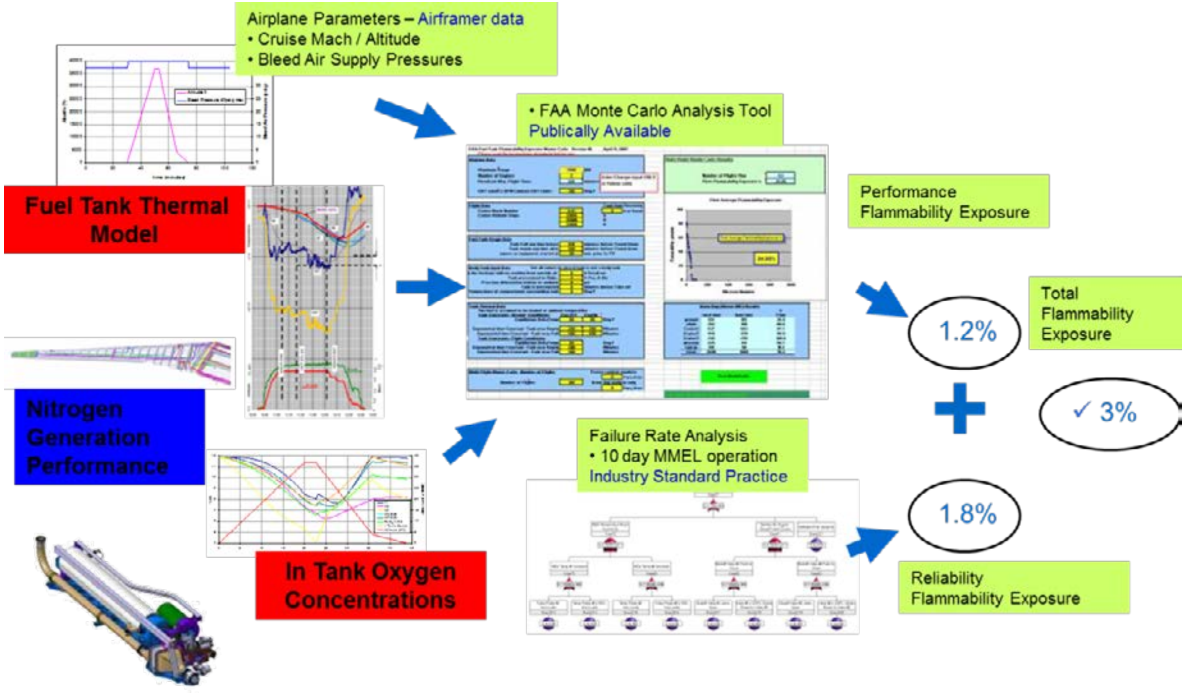
Typical fuel tank FRM model



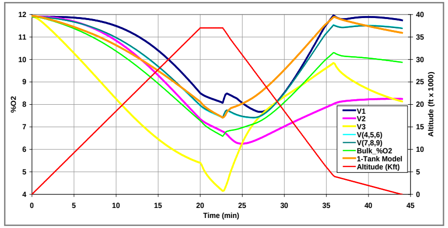
Air separation module tests

Distribution certification test

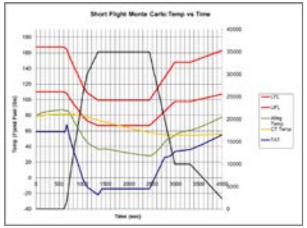
Full size distribution test rig

FAR 25.981 – fully validated tank modeling

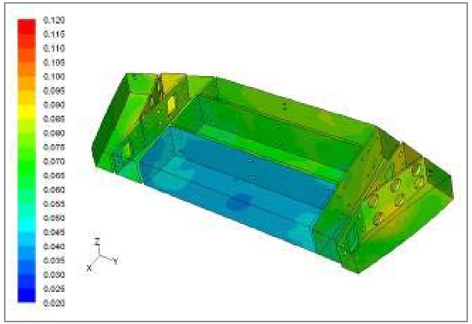
Climb	Cruise	Descent



Tank thermal modelling

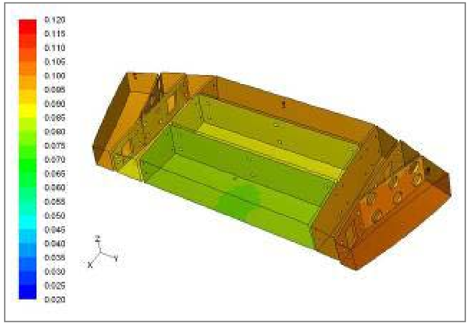


Climb / cruise flight phase



NEA flow from rear of tank to vent at front

Climb / cruise flight phase



Air enters tank through vents

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Questions/Comments

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