FAA Triennial Fire Safety Conference

November 1st

Inerting Systems for Commercial Airplanes

Alan Grim

Overview

- Brief History
- System Overview
- Airplane Safety Considerations
- Hot Day Operations
- Design Goal
- Implementation
- Future Design

Brief History

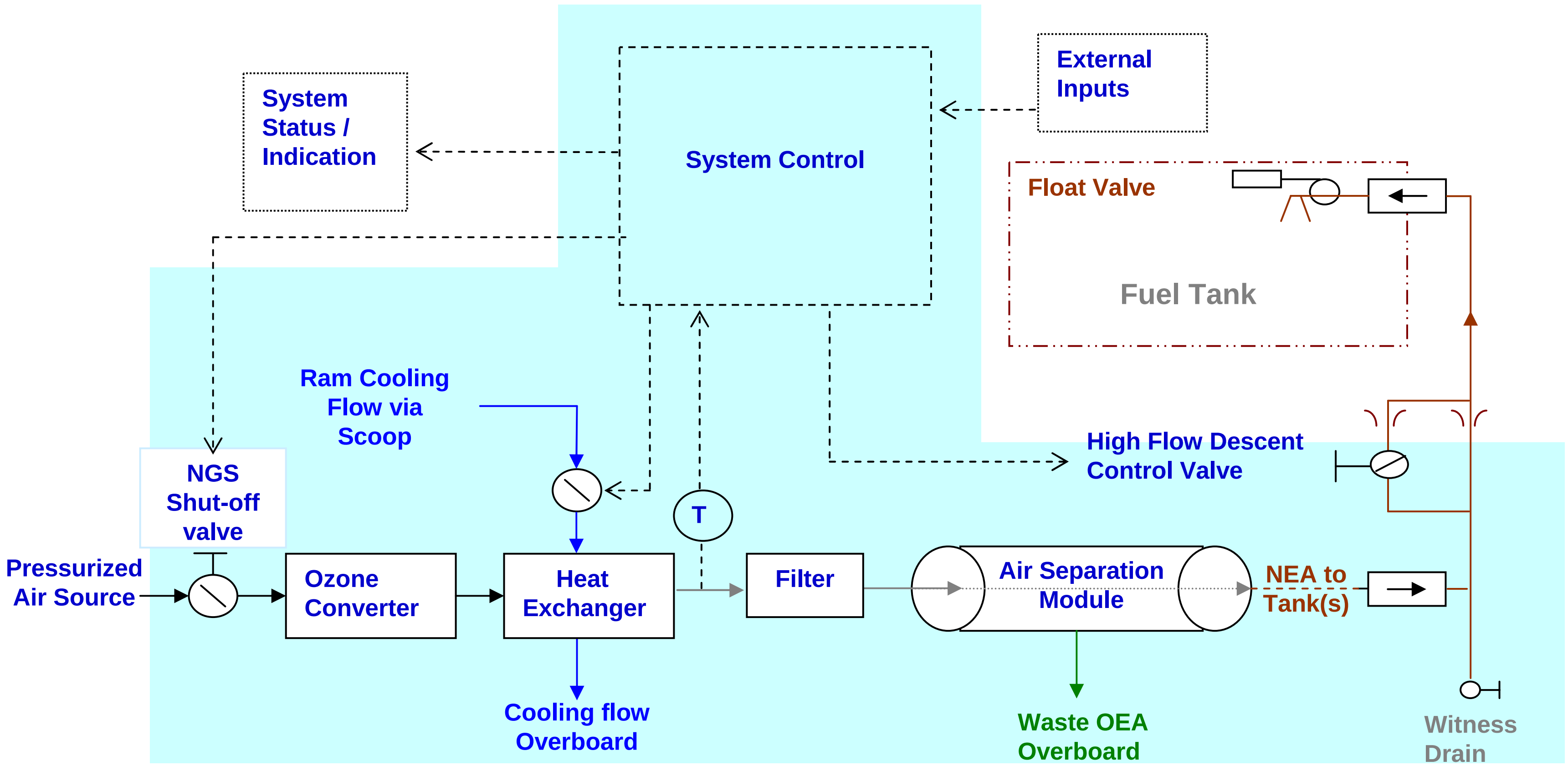
- 1996 NTSB Recommendations following Flight 800 accident included Flammability Reduction
- FAA initiated ARAC teams to study flammability reduction and inerting for commercial use
- 1998 ARAC Studied flammability reduction options
  - Recommended rule for new design to reduce flammability
- 2001 ARAC focused on Inerting
  - Ground based
  - On board in flight
  - System still not practical in 2001
    - Cost, weight, reliability all issues
  - Recommended further development of onboard generation

Brief History (Cont'd)

- **Enablers for commercial airplane inerting system development**
  - **FAA testing validated that an Inert Benchmark of 12% O2 precludes significant pressure rise for vast majority of commercial conditions**
  - **Use of Hollow Fiber Membranes**
  - **Applying an average risk fleet wide safety assessment (Monte Carlo)**
    - **Reducing flammability exposure to levels at least equivalent to wing tanks will provide an order of magnitude improvement**
  - **Defining the system as non-critical to airplane operations**
    - **Use of inerting as an additional level of protection to ignition protection**
  - **Focus on high flammability exposure tanks**

Generic System Overview

Nitrogen Generation System (NGS)



NEA – Nitrogen Enriched Air
OEA – Oxygen Enriched Air

BOEING®

System Overview

- Airplane bleed or compressor flow/pressure source of air
  - Air temperature of up to 450F
    - Too hot for current fiber to handle
  - ASM requires warm air with as much pressure as available
- Cooling of air source required
  - Ram air for cooling source
  - Control temperature to ASM for optimum performance
- ASM separates O2 from air to generate NEA
  - Purity dependant on pressure available
  - OEA exhausted overboard
  - NEA supplied to tank

System Overview

- Multiple flow modes used to reduce bleed consumption
  – Low flow typically used in climb and cruise
    - Inerting performance good
    - Bleed flow conserved – directly related to fuel burn
  – High flow used during descent
- Vent system modifications may be required
  – Boeing Puget Sound airplanes vent to both wing tips
  – Condition dubbed “cross-venting” results
  – Design feature required to prevent “cross-venting”

System Overview

- **Distribution system**
  - **System size and geometry dependent on even distribution of NEA**
  - **Tank structure will have an effect on distribution**
  - **Discrete vent points will affect design**

Safety Considerations

- Design Precautions that must be addressed to preclude creating additional hazards
  - Prevent potential new ignition sources inside fuel tank
    - Bond for electrostatics
    - Prevent lightning energy entering tank
    - 450F air indirectly connected to fuel tank
      - System must absolutely preclude 450F air from reaching tank
      - Requires redundant independent shutoff methods
  - Minimize impact of air source on existing systems
    - Cabin pressurization
    - Ability to evacuate smoke from cabin
    - Engine performance

Safety Considerations

- Potential hazards to maintenance personnel
  - Areas outside fuel tank where NGS is installed or routed
    - Limit NEA concentration to protect maintenance personnel
    - Placards in affected area
  - Fuel tank
    - Requirement drives tank to 02 levels below 12%
    - Emphasize existing purging procedures
    - Placards adjacent to tank access doors
- Modifications to fuel tank vent system must not result in tank over/under pressure conditions
  - NGS failures
  - Rapid climb or emergency descent
  - Refueling failure cases

Hot Day Operations

- Unexplained accidents occurred on 80F ambient temps and greater
  - 2 ground incidents and 1 climb incident
- Analysis shows significant flammability exposure on 80+ F days
  on ground and in climb
- FAA Special Condition covers this scenario
  - 3% Fleet Average limit
  - 3% Ground on 80^{+}F days limit
  - 3% Climb on 80^{+}F days limit
- 80^{+}F Ground and climb requirement will likely be system size driver

BOEING®

Design Goal

- Enhance fuel system safety through development of a practical and effective Nitrogen Generation System
  - Minimize flammability exposure
  - Address ground and climb operations on warm days
  - Design to achieve 10 day MMEL Classification
  - Minimize bleed air use impact on fuel burn
  - Minimize weight impact
  - Minimize scheduled maintenance
- Ensure Service Ready

Implementation

- Certification requirements are specified in FAA/EASA Special Conditions
- NGS is new technology for commercial airplanes
  - Extensive developmental and qualification testing required
  - Ground and flight testing to validate operation
- In-Service Evaluation to ensure NGS is service ready
  - The Boeing ISE began in 2005 on two 737-700s and two 747-400s
  - Over 30,000 Total NGS Hours and 10,000 NGS Cycles accumulated
  - The ISE demonstrated that NGS had no impact on the normal daily airplane operation
- Introduce design enhancements before full production incorporation

Implementation

- **Design enhancements**
  - **Service life / durability issues discovered during qualification testing resulting in life limited parts in ISE**
  - **ISE confirmed qualification test concerns**
  - **Cause and necessary corrective action determined**
- **Design improvements incorporated prior to full production**
  - **Additional qualification and flight testing will validate final design**
  - **Intended to meet initial service life objectives and reduce scheduled maintenance**
- **Service ready system and maintenance support structure in place**

Future Design

- **Future fuel system design will include both ignition prevention and flammability reduction features**
  - **Code of Federal Regulations, Part 25 was amended in 2001 to enhance fuel tank safety standards**
    - **Ignition prevention requirements were enhanced**
    - **Flammability minimization requirements were added**
- **FAA and EASA rule making in process to determine if flammability minimization will be mandated for production and in-service airplanes**
- **Boeing to begin delivery of service ready Nitrogen Generation Systems in production airplanes beginning in 2008**