FAA Triennial Fire Safety Conference

November 1st

Inerting Systems for Commercial Airplanes

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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)

- System Status / Indication
- External Inputs
- System Control
- Fuel Tank
- Float Valve
- High Flow Descent Control Valve
- NGS Shut-off valve
- Pressurized Air Source
- Ozone Converter
- Heat Exchanger
- Filter
- Air Separation Module
- NEA to Tank(s)
- Waste OEA Overboard
- Cooling flow Overboard
- Witness Drain

NEA – Nitrogen Enriched Air
OEA – Oxygen Enriched Air
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
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