FAA R&D Efforts on Flammability

Ivor Thomas

Chief Scientific and Technical Advisor to the FAA,

Fuel System Design

August 14th 2002

ivor.thomas@faa.gov

Why Reduced Flammability?

- Some tanks on some airplanes heated by nearby systems,
- These tanks are the ones involved with last three accidents
- FAA considers that tank safety level required needs both improved ignition prevention AND reduced flammability

FAA R&D

- Developed flammability envelope as a function of ignition energy
- Developed Fuel:Air Ratio computer program to examine effects of flash point, distillation and tank fuel load on flammability envelope
- Test program to examine fuel vapor build-up in tank
- On-going work to model time histories to better assess flammability in dynamic tank.

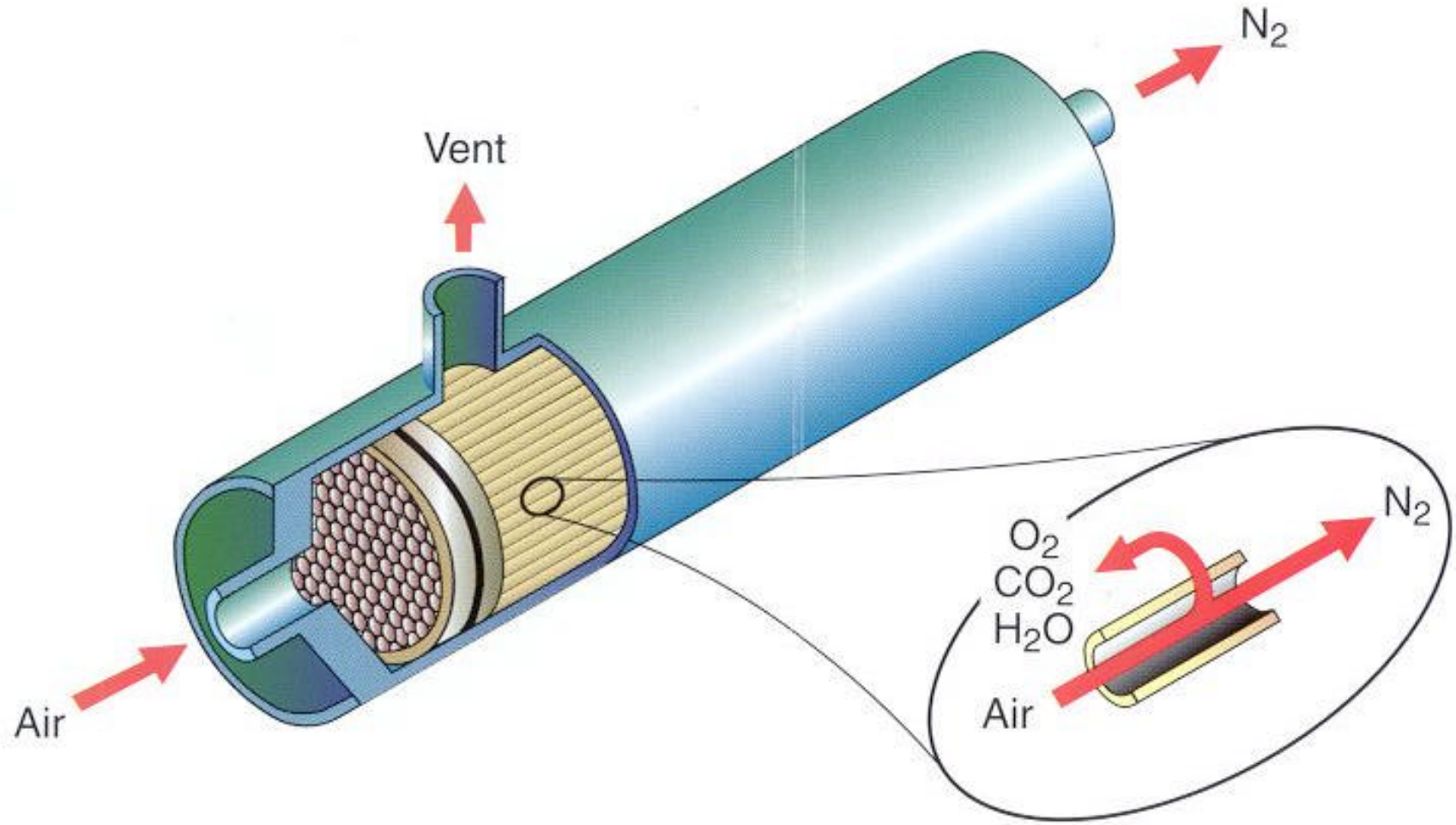
FAA R&D

- Developed Flammability Exposure Model to assess flammability of any tank
  - Model was basis for most of ARAC group analysis of flammability/inerting effectiveness
- Developed Inerting Design Model to size inerting system for specific airplane
  - Used extensively by ARAC group, OEM's and FAA.

FAA R&D

- Test Program to examine behavior of Permeable membrane NEA (Nitrogen Enriched Air) generation system and to examine ground based inerting (GBI) recommended by ARAC.
- Study of Cost of GBI
- Study of benefits of inerting on survivable accidents

ASM (Air Separation Module)



FAA R&D

- Joint FAA/Boeing flight test of GBI on 737 NG
- Test Program to evaluate oxygen levels needed to inert tank
- Test Program to evaluate lower flammability limits (LFL) to cross-check earlier predictive work

FAA R&D

- Purchase of 747 SP to further inerting work
- Installation of inerting system in 747SP to examine full scale effects of inerting and flammability development with packs running
- Development of ¼ scale 747 CWT to develop design technique to find simplest and most effective in tank distribution system

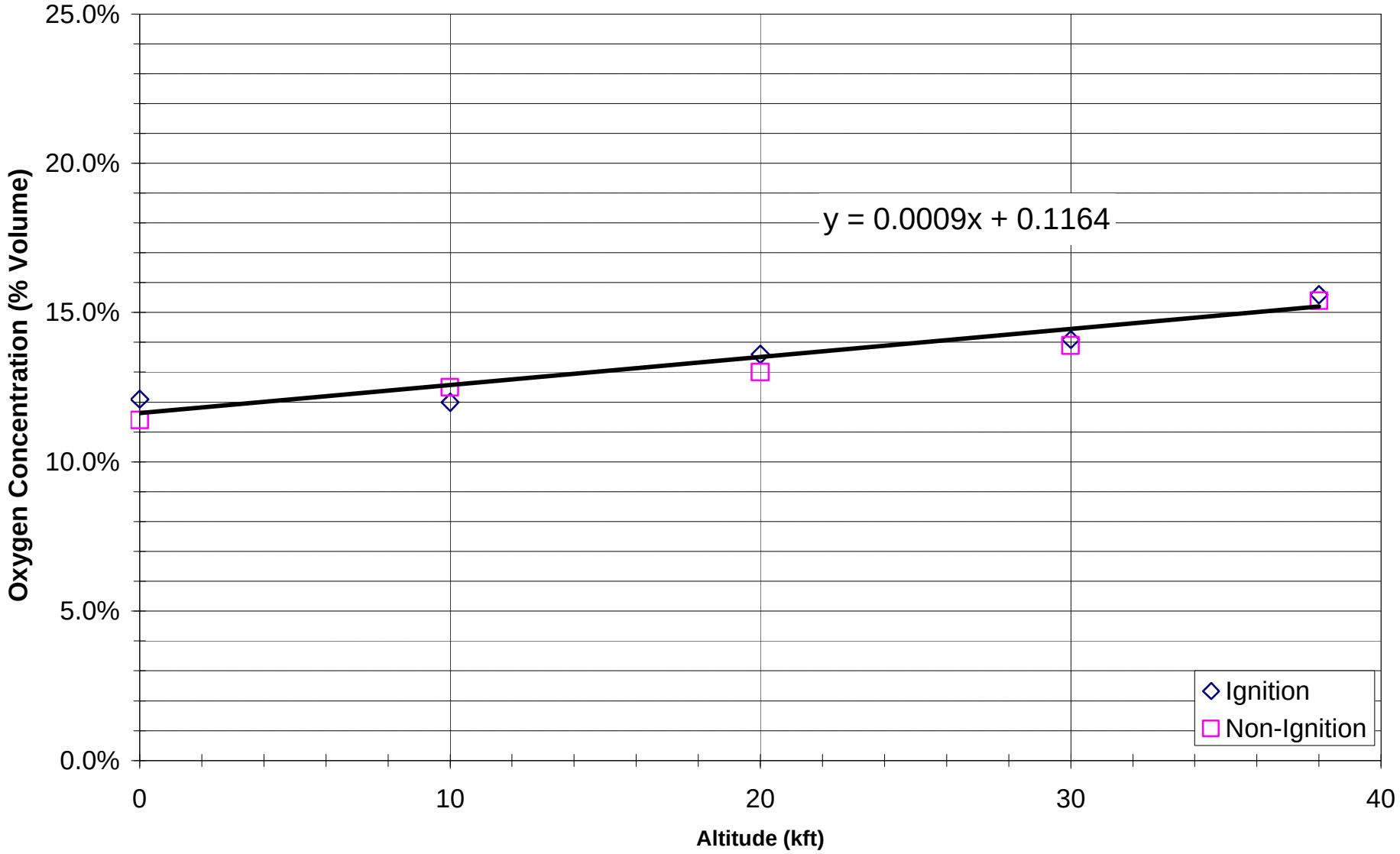
Recent Significant Progress

- 737 testing
  - Verified tank stays inert on ground for long periods without needing to add nitrogen
  - Need to avoid cross-venting to prevent loss of nitrogen on ground and in flight

Recent Significant Progress

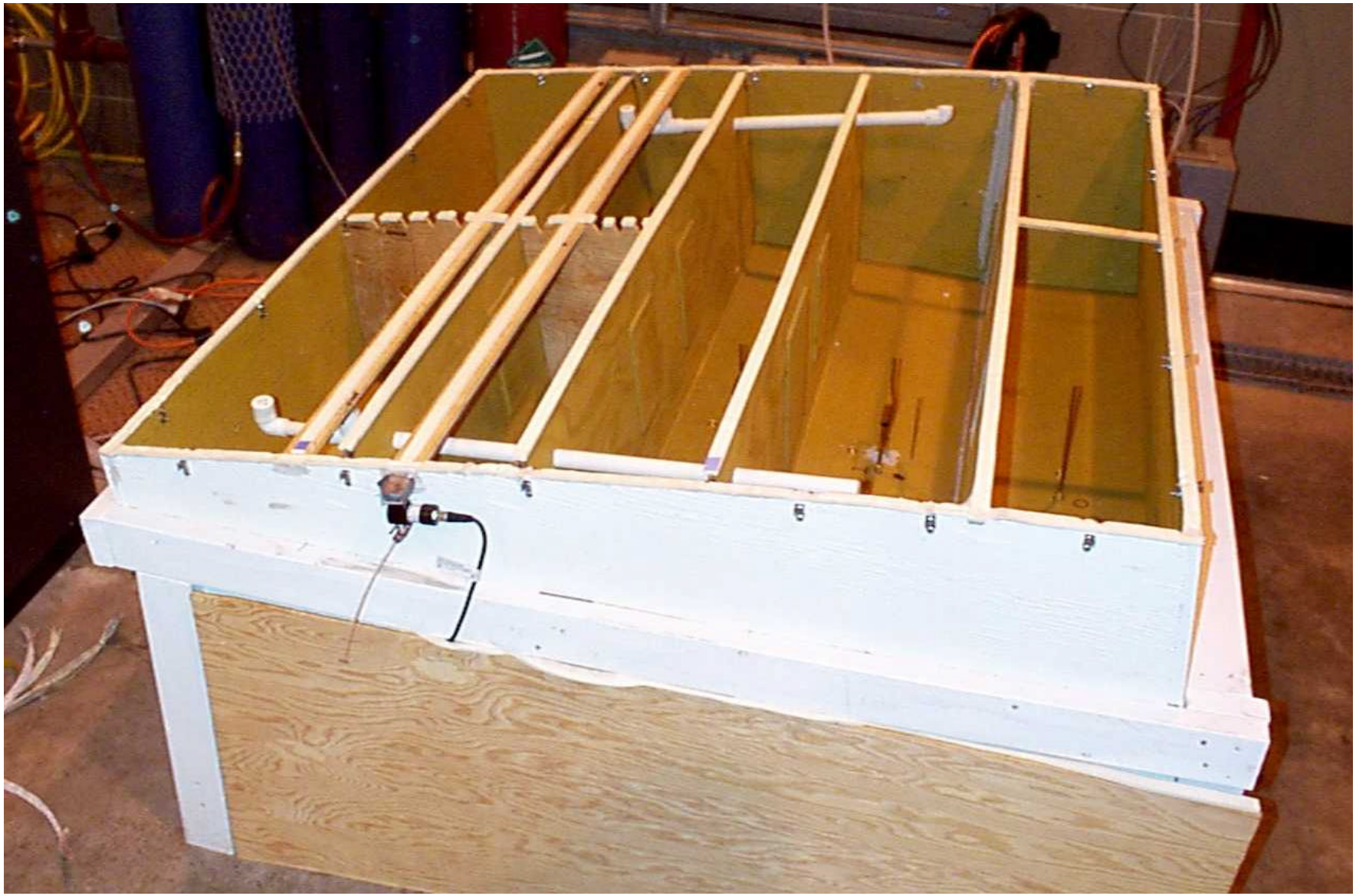
- Inert system O2 requirements
  - Showed that O2 levels need only be 11.5% on ground and 15.5% at altitude
  - Testing conducted with very large spark (20 joules) to be conservative

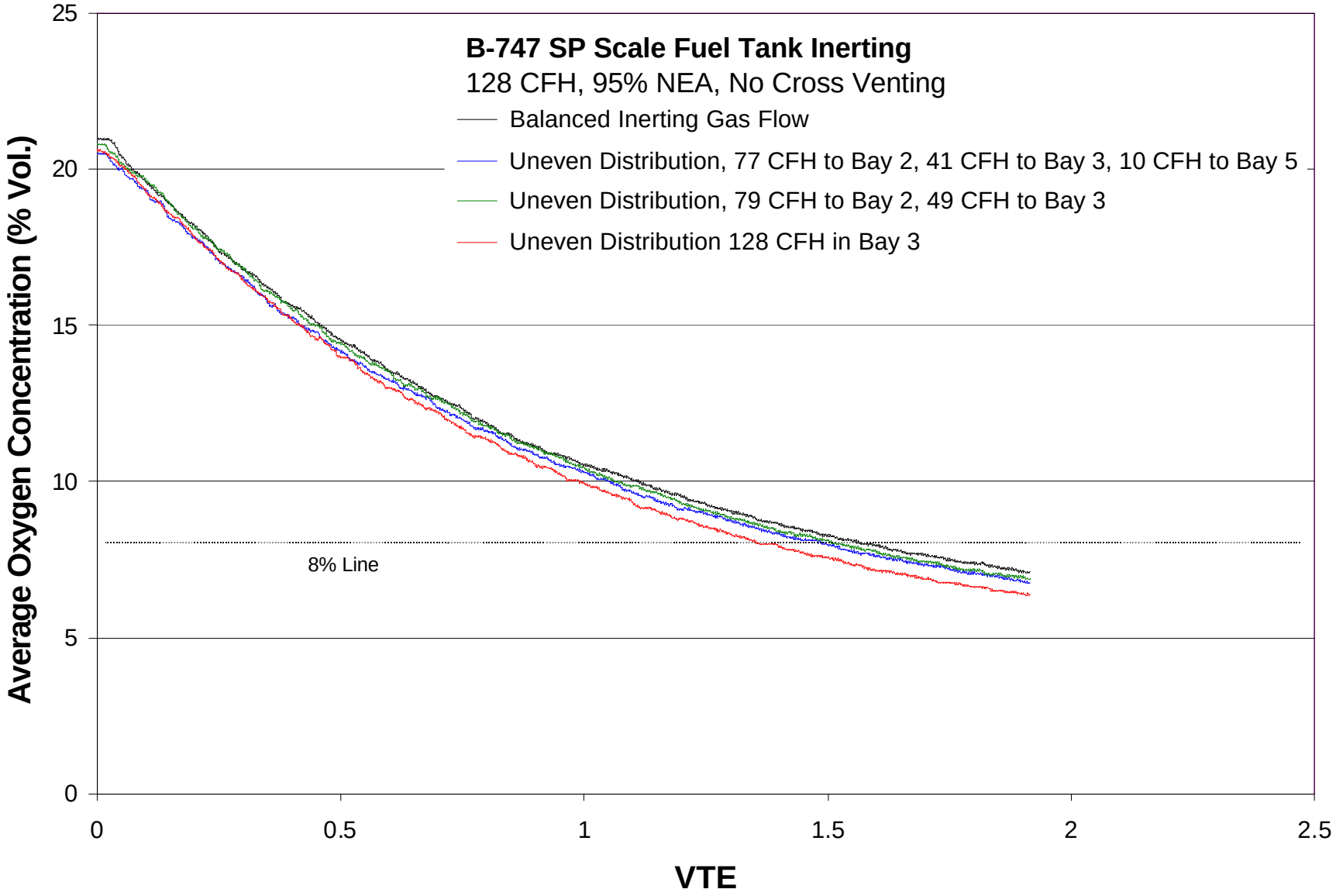
Minimum Values For Ignition and Maximum Values for Non-Ignition Plotted Vs. Altitude



Recent Significant Progress

- 747 scale model and actual airplane test
  - Showed that complex distribution manifold in tank not needed
  - Simple single line into one bay was much more efficient than complex manifold



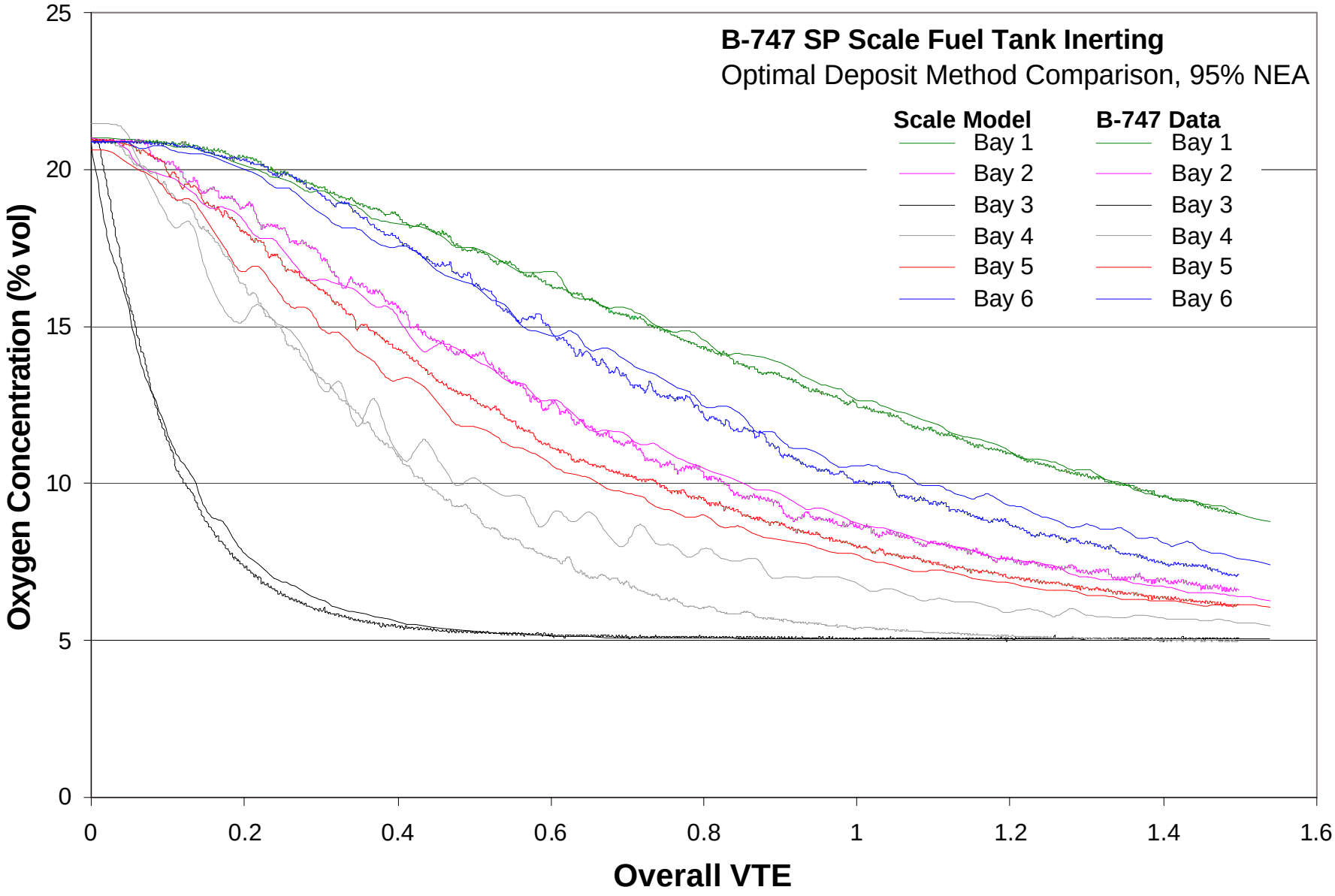

B-747 SP Scale Fuel Tank Inerting
128 CFH, 95% NEA, No Cross Venting
Balanced Inerting Gas Flow
Uneven Distribution, 77 CFH to Bay 2, 41 CFH to Bay 3, 10 CFH to Bay 5
Uneven Distribution, 79 CFH to Bay 2, 49 CFH to Bay 3
Uneven Distribution 128 CFH in Bay 3
8% Line
Average Oxygen Concentration (% Vol.)
VTE
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5

Recent Significant Progress

- Airplane Bleed System Performance
  - Reexamination of bleed system performance and reduced inerting system demand shows that current bleed systems can support inerting system in flight.
  - Fuel penalty for dual-flow inerting system is approximately 2 lb/hour for single aisle airplane

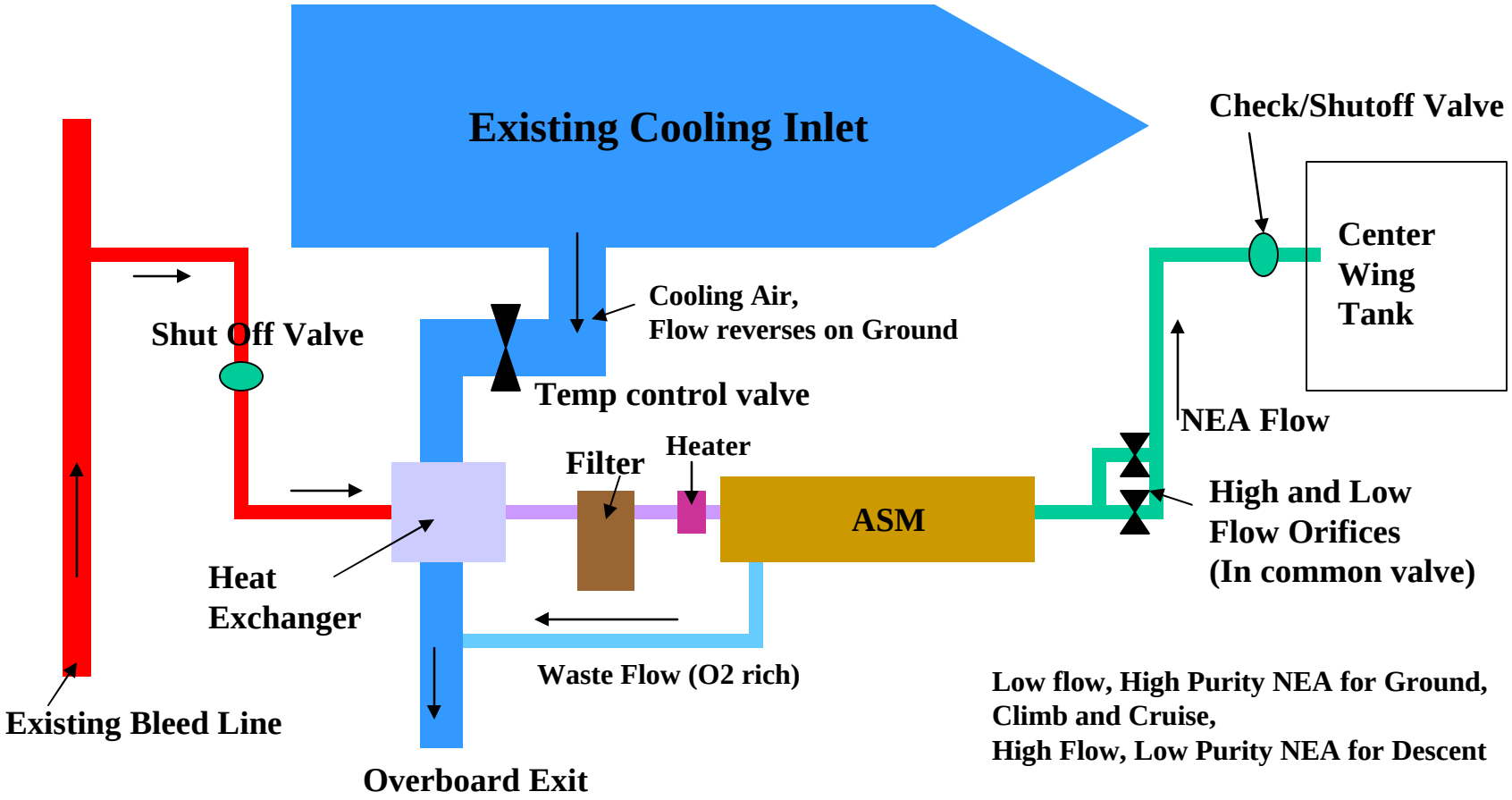
Recent Significant Progress

- Scale Model Testing
  - Tests using a ¼ scale model have been shown to be very cost effective and highly representative of the full scale airplane.
  - Scale model tests have confirmed simple distribution system efficacy
  - Scale model to be used for climb/dive tests of system

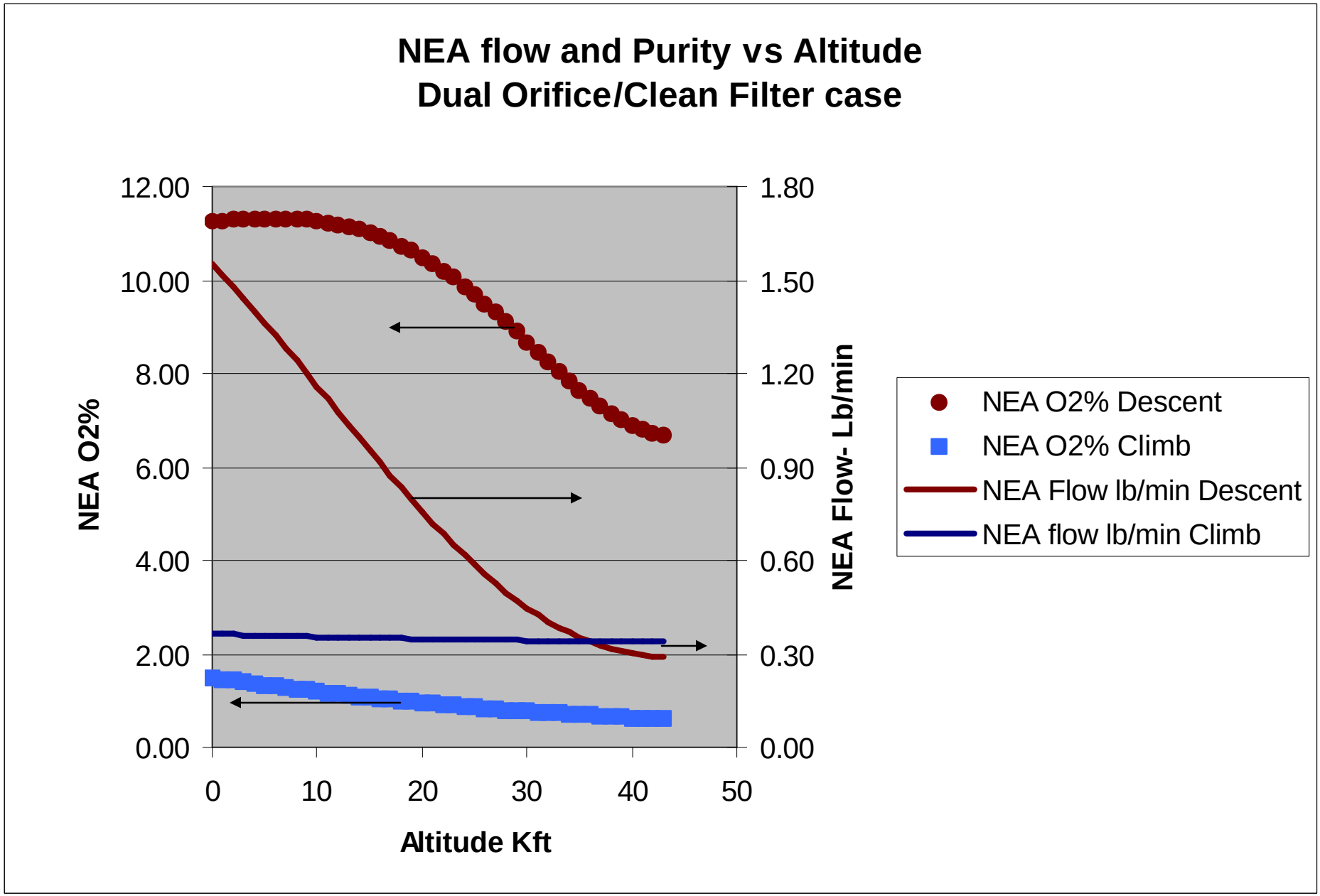

B-747 SP Scale Fuel Tank Inerting
Optimal Deposit Method Comparison, 95% NEA
Scale Model
Bay 1
Bay 2
Bay 3
Bay 4
Bay 5
Bay 6
B-747 Data
Bay 1
Bay 2
Bay 3
Bay 4
Bay 5
Bay 6
Oxygen Concentration (% vol)
25
20
15
10
5
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Overall VTE

Recent Significant Progress

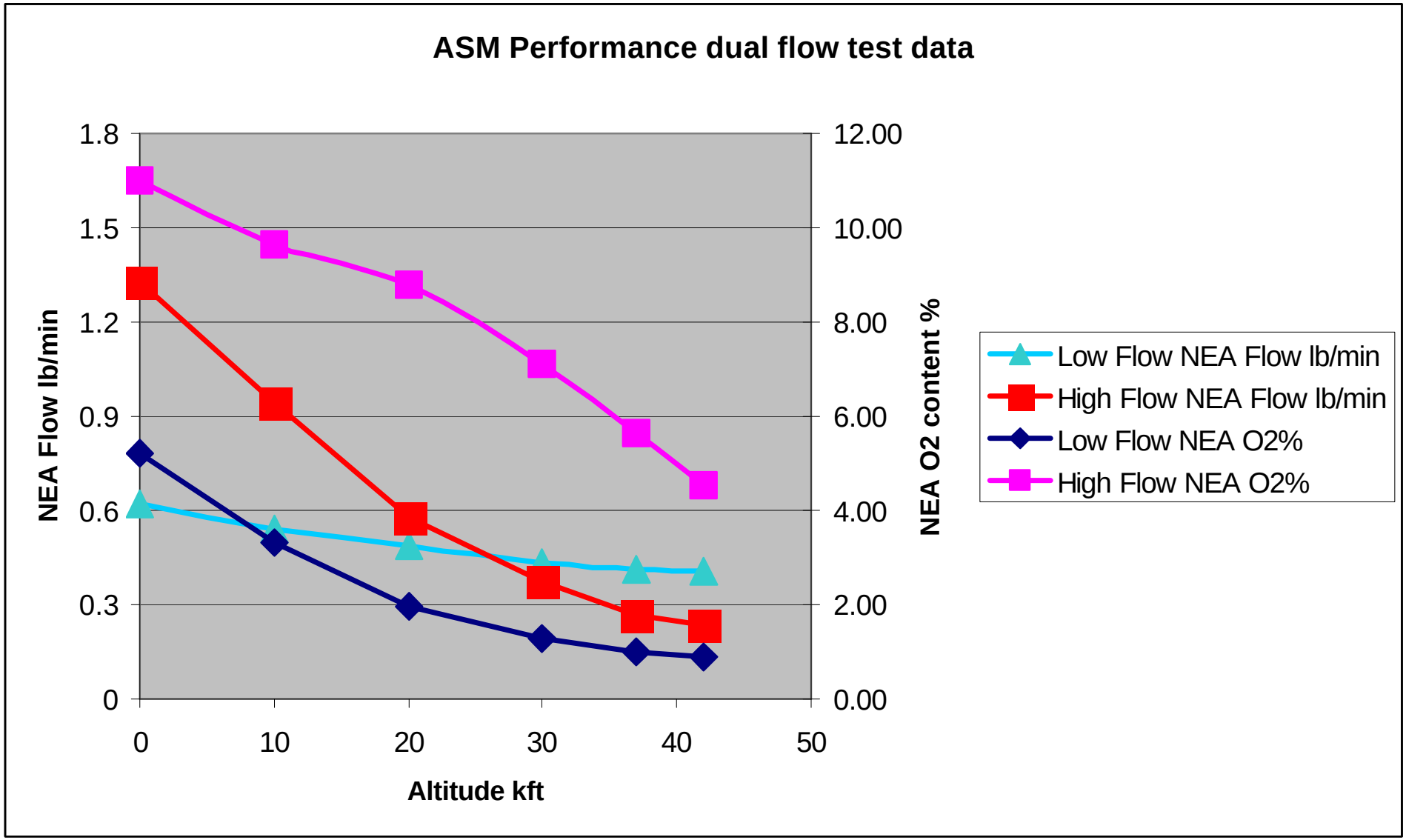
- Inerting System Dual flow Concept
  - Use of low flow high purity mode in climb and cruise coupled with a high flow, low purity mode for descent provides virtually full time inerting, without running on the ground.
  - Simple system eliminates compressor, cooling fan, only moving parts are shutoff valves and a temperature regulator

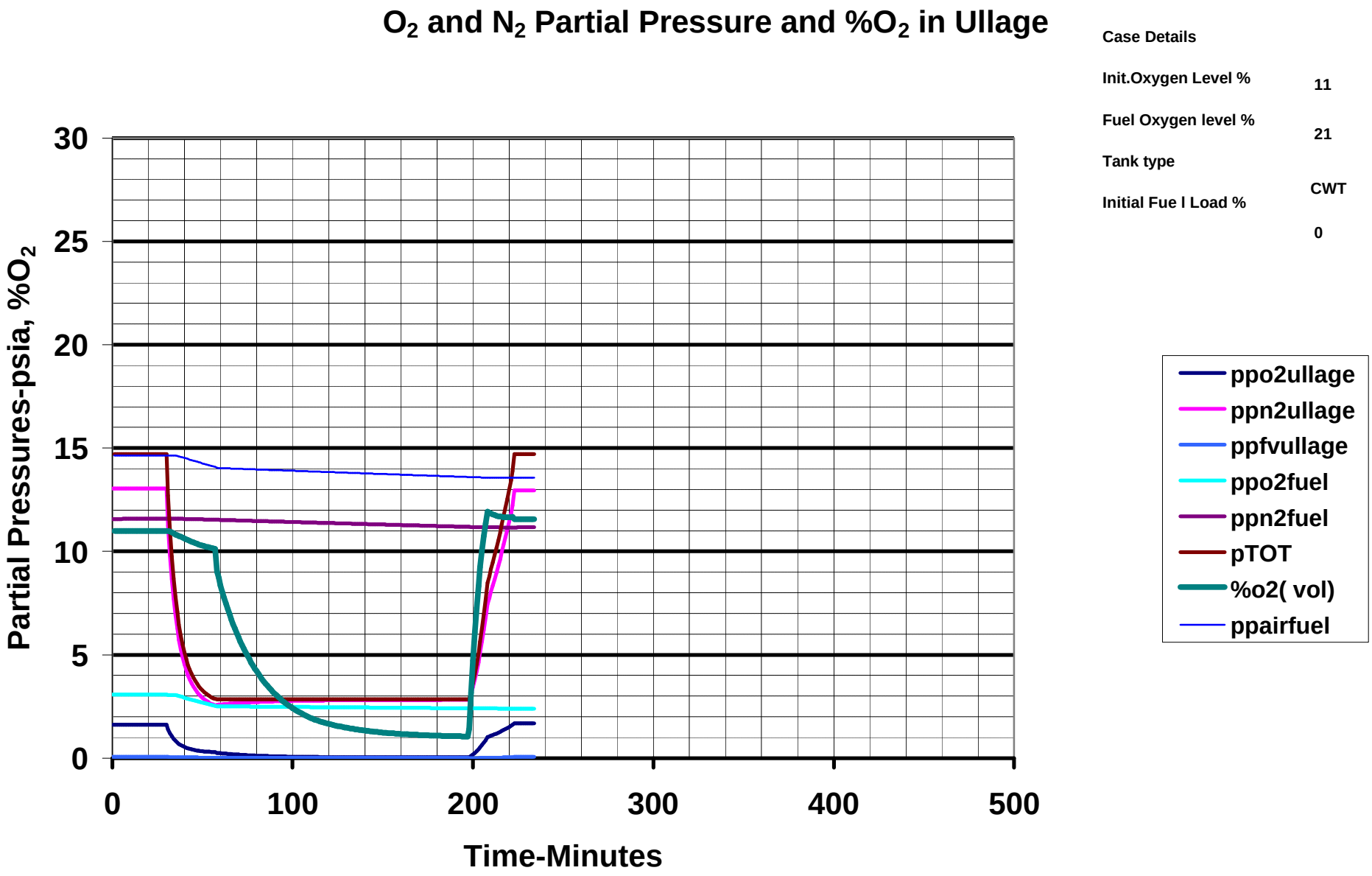


Simple Full-Time Inerting System


NEA flow and Purity vs Altitude
Dual Orifice/Clean Filter case
12.00
10.00
8.00
6.00
4.00
2.00
0.00
NEA O2%
1.80
1.50
1.20
0.90
0.60
0.30
0.00
NEA Flow- Lb/min
0
10
20
30
40
50
Altitude Kft
NEA O2% Descent
NEA O2% Climb
NEA Flow lb/min Descent
NEA flow lb/min Climb

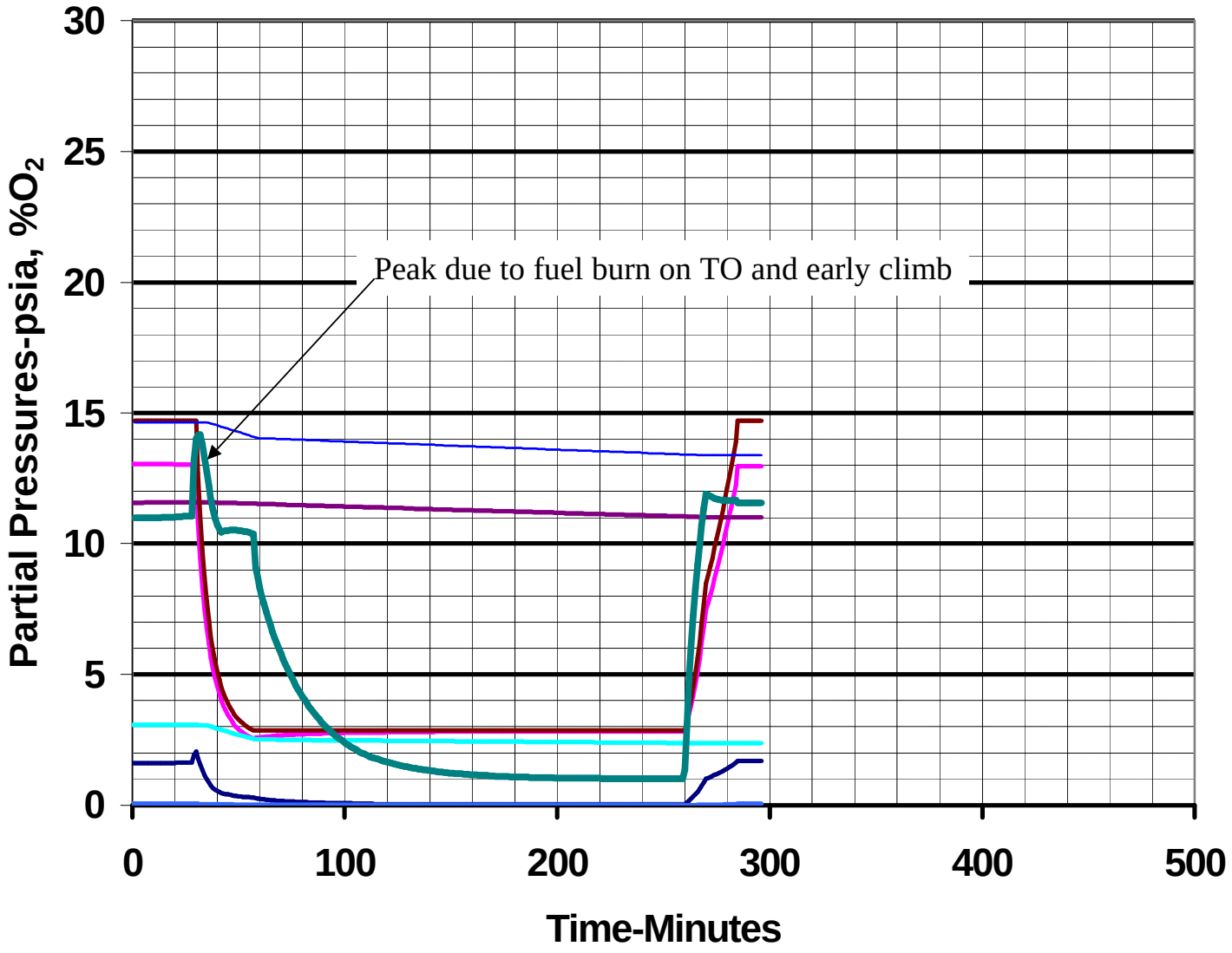
Preliminary data, subject to review




O_2 and N_2 Partial Pressure and $\%O_2$ in Ullage
Case Details
Init.Oxygen Level %
11
Fuel Oxygen level %
21
Tank type
CWT
Initial Fue l Load %
0
Partial Pressures-psia, $\%O_2$
30
25
20
15
10
5
0
0
100
200
300
400
500
Time-Minutes
ppo2ullage
ppn2ullage
ppfvullage
ppo2fuel
ppn2fuel
pTOT
%o2(vol)
ppairfuel

O_2 and N_2 Partial Pressure and $\%O_2$ in Ullage

Dual Orifice, Long flight- 200 minutes cruise duration



Case Details	
Init.Oxygen Level %	11
Fuel Oxygen level %	21
Tank type	CWT
Initial Fue l Load %	85

- ppo2ullage
- ppn2ullage
- ppfvullage
- ppo2fuel
- ppn2fuel
- pTOT
- %o2(vol)
- ppairfuel

Initial Conclusions

- Benefits of this approach:
  - Very Simple system, no compressor
  - No ground running needed
  - High reliability; Only moving parts are cooling flow modulating valve, plus shut off valves, plus flow controller (Regulator or two position orifice)
  - Low weight 50 lb + manifold to tank (737/A320 size Center Tank)
  - Minimum impact on airplane

Questions

- Need to verify ASM performance under low pressure/high altitude conditions
- Need to verify fuel tank Oxygen content/distribution during descent with air and NEA entering tank.

Work In progress

- Testing ASM performance under low pressure/high altitude conditions (This week)
- Test of fuel tank oxygen content and distribution during descent with air and NEA entering tank. Test planned to start as soon as ASM testing complete

Work In progress

- Working with Boeing to develop flight test of the dual flow system in the fall of 2002